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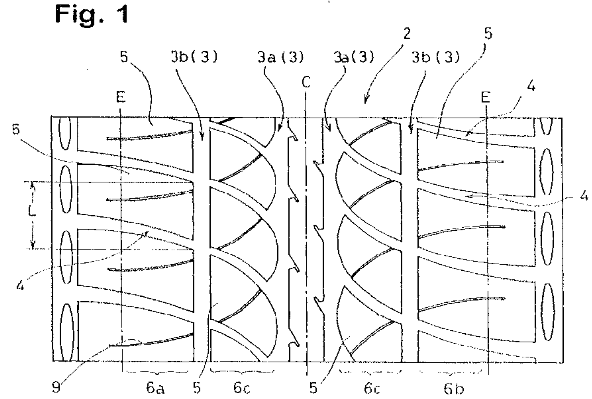
(54) Pneumatic tyre

(57) A pneumatic tyre comprises a tread portion (2) provided with a series of design-cycles repeating in the circumference of the tyre at variable pitches (L), wherein the number (NP) of different kinds of pitches is at least 10. The variable pitches (L) repeatedly increase and decrease alternately in one circumferential direction of the tyre to define start design-cycles from which the pitches (L) start to increase. A series of design-cycles is composed of a series of units (U), each unit (U) being defined as a group of design-cycles starting from and including one of the start design-cycles to but excluding the next start-cycle. The total number (NU) of the units is from 4 to 20. The units consists of at least one first-unit the number of which is 20 to 80% of the total number, at least one second-unit the number of which is 20 to 80% of the total number, and optionally a third-unit the number of which is 0 to 60% of the total number. The first unit is defined as including at least one pitch which is not less than a standard long pitch (PLa) and at least one pitch which is not more than a standard short pitch (PSa). The second unit is defined as including at least one pitch within one of the following two ranges, a range of not less than the standard long pitch (PLa) and a range of not more than the standard short pitch (PSa), but no pitch within the other range. The third unit is defined as all the pitches therein are more than the standard short pitch (PSa) and less than the standard long pitch (PLa). The standard long pitch (PLa) is the maximum pitch (PL) minus a length of 0.2 times a maximum pitch difference (MPD). The standard short pitch (PSa) is the minimum pitch (PS) plus a length of 0.2 times the maximum pitch difference (MPD), and the maximum pitch difference (MPD) is the maximum pitch (PL) minus the minimum pitch (PS).

Fig. 1



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Description

The present invention relates to a pneumatic tyre improved in tread pattern noise, more particularly to an improvement in a variable pitching method.

In general, tyres are provided in the tread portion with circumferentially spaced tread elements constituting a tread pattern such as blocks for good road grip. During running, such tread elements contact with road surface one after another, and a sound called pattern noise is generated.

In order to reduce such pattern noise the so called variable pitching methods have been proposed. By these methods, pattern noise is modulated into a wide frequency range so that the pattern noise turns to the so called white noise. For example, in each of laid-open Japanese patent application Nos. JP-A-8-108711, JP-A-8-113012 and JP-A-8-113013, such a method is disclosed.

In variable pitching methods, by increasing the number of different pitches, it becomes easy to turn pattern noise to white noise. However, when the pitch number is large, the rigidity of the tread elements is liable to become uneven and uneven wear increases.

It is therefore, an object of the present invention to provide a pneumatic tyre, in which the occurrence of uneven wear can be controlled in spite of a relatively large number of different pitches used therein to improve pattern noise.

According to one aspect of the present invention, a pneumatic tyre comprises a tread portion being provided with a series of design-cycles repeating in the circumference of the tyre at variable pitches, wherein the number (NP) of different kinds of pitches is at least 10, characterised in that said variable pitches repeatedly increase and decrease alternately in one circumferential direction of the tyre to define start design-cycles from which the pitches start to increase, said series of design-cycles being composed of a series of units, each unit being defined as a group of design-cycles starting from and including one of the start design-cycles to but not including the next start-cycle, the total number of the units being in the range of from 4 to 20, each the unit consists of at least one first-unit the number of which is 20 to 80% of said total number, at least one second-unit the number of which is 20 to 80% of said total number, and optionally a third-unit the number of which is 0 to 60% of said total number, wherein the first unit is defined as including at least one pitch which is not less than a standard long pitch (PLa) and at least one pitch which is not more than a standard short pitch (PSa), the second unit is defined as including at least one pitch within one of the following two ranges, a range of not less than the standard long pitch (PLa) and a range of not more than the standard short pitch (PSa), but no pitch within the other range, the third unit is defined as all the pitches therein are more than the standard short pitch (PSa) and less than the standard long pitch (PLa), the standard long pitch (PLa) is the maximum pitch (PL) minus a length of 0.2 times a maximum pitch difference (MPD), the standard short pitch (PSa) is the minimum pitch (PS) plus a length of 0.2 times the maximum pitch difference (MPD) and the maximum pitch difference (MPD) is the maximum pitch (PL) minus the minimum pitch (PS).

Embodiments of the present invention will now be described in detail in conjunction with the accompanying drawings, in which:

Fig.1 is a partial developed plan view of a pneumatic tyre according to the present invention showing an example of the tread pattern;

Fig.2 is a graph showing the sequence of the pitches of the design-cycles (tread blocks) thereof in the tyre circumferential direction;

Fig.3 is a graph showing all the pitches thereof in descending order;

Figs.4 to 19 each show the pitch sequence and the pitches in descending order of Examples 1 to 16, respectively, of the present invention; and

Figs.20 to 25 each show the pitch sequence and the pitches in descending order of References 1 to 6, respectively.

The pneumatic tyre according to the present invention comprises a tread portion 2, a pair of axially spaced bead portions, and a pair of sidewall portions extending between the tread edges and the bead portions. The tyre may be reinforced by a carcass extending between the bead portions, a bead core disposed in each bead portion, and a belt disposed radially outside the carcass in the tread portion.

The tread portion 2 is provided with tread grooves 3 and 4 to form a tread pattern. The tread pattern comprises a series of design-cycles repeating around the circumference at variable pitches (L). The number (NC) of design-cycles is preferably 50 to 90. The number (NP) of different kinds of pitches (L) is preferably at least 10. Further, the maximum pitch (PL) is preferably set in the range of from 120 to 170 % of the minimum pitch (PS) to prevent uneven wear.

Taking the example shown in Figs.2 and 3, the pitch sequence according to the invention will now be explained. In Fig.2, the design-cycle is indicated on the horizontal axis, and the pitch is indicated on the vertical axis.

In Fig.2, from the first design-cycle to the last (70th) design-cycle, considered in the tyre circumferential direction, the pitches repeatedly increase and decrease alternately. Accordingly, there are a plurality of design-cycles (hereinafter start-cycles) from which the pitch starts to increase.

Here, using such start-cycles, a unit (U) is defined as a group of design-cycles starting from and including a start-cycle to but not including the next start-cycle.

Accordingly, there is one peak of the pitches in each unit (U). In Fig.2, for example, the lst-6th cycles are unit U1, the 7th-10th cycles are unit U2, the llth-20th cycles are unit U3, the 45th-51st cycles are unit U7, and there are ten such units (U1 to U10) in the pitch sequence.

Each pitch sequence is made up of 4 to 20 units, preferably 8 to 20 units, more preferably 9 to 13 units. If the total number (NU) of units is less than 4, periodicity is liable to happen in the pitch variation in the tyre circumferential direction, and uncomfortable sound increases. If the total number (NU) of units is more than 20, it is difficult to improve noise and uneven wear. It is especially difficult in a pneumatic tyre comprising 50 to 90 design-cycles.

In the present invention, however, noise and uneven wear can both be improved by using three types of units the numbers of which are specifically limited in relation to the total number (NU).

First, a maximum pitch difference (MPD) is defined as the maximum pitch (PL) minus the minimum pitch (PS). A standard long pitch (PLa) is defined as the maximum pitch (PL) minus a length of 0.2 times the maximum pitch difference (MPD). Further, a standard short pitch (PSa) is defined as the minimum pitch (PS) plus a length of 0.2 times the maximum pitch difference (MPD).

The percentage D(%) in number, of the units of one type (hereinafter first unit), which is defined as including at least one pitch which is not less than the standard long pitch (PLa) and at least one pitch which is not more than the standard short pitch (PSa), is 20 to 80% of the total number of the units in a pitch sequence. In Fig.2, for example, the first units are U1, U3, U5, U6, U7, U8 and U9. Thus percentage (D) is 70%.

The percentage R(%) in number, of the units of another type (herein after second unit), which is defined as including at least one pitch within one of the following two ranges, a range of not less than the standard long pitch (PLa) and a range of not more than the standard short pitch (PSa), but no pitch within the other range, is 20 to 80% of the total number of the units in a pitch sequence. In Fig.2, for example, the second units are U2 and U10. Thus, the percentage (R) is 20%.

The percentage N(%) in number, of the units of the remaining type (hereinafter third unit), all the pitches of which are more than the standard short pitch (PSa) and less than the standard long pitch (PLa), is 0 to 60% of the total number of the units in a pitch sequence. In Fig.2, for example, the third unit is U4 only, and the percentage (N) is 10%.

If the percentage (D) and/or (R) is less than 20% or the percentage (D) and/or (R) is more than 80%, pattern noise is not reduced, though sometimes uneven wear is prevented.

Similarly, if the percentage (N) is more than 60%, the pattern noise can not be reduced.

In Fig.3, all the pitches in this sequence are plotted in the descending order.

The difference (V) between any of the pitches and the next longer or shorter pitch is preferably set in the range of less than 6% of the average pitch (Pa). The average pitch (Pa) is defined as the total of all the pitches in the sequence divided by the number (=NC) of all the pitches. If the pitch difference (V) is more than 6% of the average pitch (Pa), the pitch variation is too wide, and the rigidity difference in the tread blocks becomes increased and uneven wear is liable to occur.

As mentioned above, the number of different kinds of pitches is NP. Accordingly, the number of variations thereof is (NP-1). And each variation is limited in the range of not less than 6% of the average pitch (Pa) because the pitch difference (V) is so limited as mentioned above.

The number (Nm) of variations (hereinafter normal variation) which are limited in the range of from 4 to 6 % of the average pitch (Pa) is set in the range of not more than 40% of the total number (NP-1) of the variations. If the number (Nm) is more than 40% of (NP-1), the variations tend to have regularity which exerts a bad influence upon the noise frequency dispersion.

Additionally, when a plurality of third units exist in a given pitch sequence, it is preferable that the third units do not adjoin each other in the tyre circumferential direction. If the third units adjoin each other, the pitch dispersion is liable to become insufficient and the noise reducing effect decreases.

Further, it is preferable that all the units are different from each other in respect of the sequence of the pitches in the unit. If the same units exist, the pitch sequence is liable to have regularity, and the noise frequency dispersion becomes worse.

Furthermore, the difference (G) between the pitches which are actually adjacent to each other in the tyre circumferential direction is preferably set in the range of not more than 25 % of the average pitch (Pa). If the actually adjacent pitches' difference (G) is more than 25 % of the average pitch (Pa), the rigidity difference in the tread elements such as blocks tends to increase and uneven wear is liable to increase.

The above-mentioned pitch sequence is preferably applied to every circumferential row 6, 6a, 6b, 6c of blocks 5 in the tread portion 2, the blocks 5 being circumferentially separated by axial grooves 4 and axially divided by circumferential grooves 3, the circumferential grooves 3 extending continuously in the tyre circumferential direction.

In the example shown in Fig.1, the tread portion 2 is provided with a pair of axially inner circumferential grooves 3a each disposed one on each side of the tyre equator (C), and a pair of axially outer circumferential grooves 3b

disposed axially outside the inner grooves 3a.

The axial grooves 4 extend axially outwards from the circumferential grooves 3a beyond the tread edges (E). The axial grooves 4 on each side of the tyre equator are inclined to one circumferential direction. In Fig.1, the inclining direction to one side is the reverse to that on the other side. However, the inclination may be the same direction to form a directional tread pattern. The axial grooves 4 are arranged at regular or irregular intervals in the tyre circumferential direction to form blocks therebetween. By the circumferential grooves 3b and axial grooves 4, a circumferential row 6a, 6b of blocks 5 is defined along each tread edge (E), which blocks have a generally parallelogram configuration. Further, the circumferential grooves 3a and 3b and axial grooves 4, define a circumferential row 6c of blocks 5 is defined.

Here, the circumferential grooves 3 and axial grooves 4 are grooves having a width of not less than 5 mm and a depth of not less than 7 mm.

In this example, sipes 9 are further provided in the blocks 5. The sipes 9 are slits having no substantial groove width, which are thus not taken into consideration.

One design-cycle is defined as a combination of one of the blocks 5 and one of the axial grooves 4 adjacent to the blocks on one side in the circumferential direction.

Each pitch (L) can be varied by changing only the circumferential length of the block 5 or only the circumferential width of the axial groove 4 or both of them.

For example, when the above-explained pitch sequence is applied to the block row 6a, the pitches (L) can be defined at the position of the circumferential groove 3b as shown in Fig.1.

Because the number (NC) is 50 to 90, each block row consists of 50 to 90 blocks divided by the same number of axial grooves.

In the example shown in Figs.1-3, NC=70, NP=20, PL=37.8 mm, and PS=22.5 mm.

Comparison Tests

Test tyres of size 205/70R15 were made and tested for noise and uneven wear, using a 2000cc passenger car all the wheels of which were provided with test tyres. The specifications and the test results are shown in Table 1.

A) Noise test

The sound heard in the test car when run on a smooth road surface on a test course at a speed of 60 km/h was evaluated by a test driver. The results are indicated by an index in which under 3.0 means that the sound felt was uncomfortable, and 3.0 or more means that it was not felt to be uncomfortable.

B) Uneven wear test

After running for 300 km on a test course, the difference between the maximum wear and minimum wear was obtained as uneven wear based on the decrease in the axial groove depth.

From the test results, it was confirmed that the Example tyres were effectively reduced in pattern noise.

In Example tyre 10 in which the maximum of the pitch difference (V) exceeds greatly over 6% of the average pitch (Pa), uneven wear was caused.

When the number (NP) of different kinds of pitches was less than 10 (Ref.1), or the total number (NU) of the units was less than 4 (Ref.2), or the total number (NU) of the units was more than 20 (Ref.3), the pattern noise was not reduced even if the special percentages for the three types of units were employed.

On the contrary, when the percentages of the three types of units were outside the above-mentioned ranges, the noise was not reduced even when the numbers (NP) and (NU) satisfied the above-mentioned ranges (Ref.4 and Ref.6).

As described above, in the pneumatic tyres according to the present invention, as the percentages of the first to third units are specifically limited, pattern noise and uneven wear can effectively be improved.

The present invention is suitably applied to passenger car tyres, but it is also possible to apply to heavy duty tyres for trucks, buses and the like, motorcycle tyres, and so on.

Table 1

	Example																Reference					
Tire	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	3	4	5	6
Design cycle																						
NC	70	70	70	80	70	70	70	70	70	70	70	70	70	70	70	70	70	70	85	70	70	70
Pitch																						
Fig. No.	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
NP	19	10	13	17	15	17	15	15	10	10	11	11	21	19	18	16	5	13	17	17	15	16
Nm	2	5	8	1	3	3	3	5	9	0	4	8	2	2	2	3	0	8	2	2	4	5
Nm/NP-1 (%)	11	56	67	7	21	19	21	36	100	0	40	80	10	11	12	20	0	67	12	13	29	33
PL/PS (%)	167	167	167	167	157	157	154	167	153	153	164	167	167	167	167	167	167	167	167	160	157	167
Max.V/Pa(%)	5	11	5	6	7	5	5	5	6	24	8	11	5	5	5	5	13	5	6	7	5	5
Max.G/Pa(%)	25	32	12	25	28	28	20	20	19	25	21	20	31	25	21	21	25	12	29	28	20	20
Unit																						
NU	9	13	4	20	10	10	10	10	9	9	9	9	10	9	10	8	12	3	24	10	10	9
1st unit	7	6	3	4	8	4	2	2	7	5	7	5	7	5	2	6	5	3	9	10	1	1
D (%)	78	46	75	20	80	40	20	20	78	56	78	56	70	56	20	75	42	100	38	100	10	11
2nd unit	2	7	1	14	2	5	7	2	2	4	2	4	3	3	2	2	5	0	15	0	8	2
R (%)	22	54	25	70	20	50	70	20	22	44	22	44	30	33	20	25	42	0	62	0	80	22
3rd unit	0	0	0	2	0	1	1	6	0	0	0	0	0	1	6	0	2	0	0	0	1	6
N (%)	0	0	0	10	0	10	10	60	0	0	0	0	0	11	60	0	16	0	0	0	10	67
Noise	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2.8	3	3	3	3	3
Uneven wear *	GD	GD	GD	GD	GD	GD	PR	GD	GD	PR	GD	GD	GD	GD	GD	GD	GD	GD	GD	GD	GD	GD

*) GD=good, PR=poor.

Claims

1. A pneumatic tyre comprising a tread portion (2), the tread portion (2) being provided with a series of design-cycles repeating in the circumference of the tyre at variable pitches (L), wherein the number (NP) of different kinds of pitches is at least 10, characterised in that said variable pitches (L) repeatedly increase and decrease alternately in one circumferential direction of the tyre to define start design-cycles from which the pitches (L) start to increase, said series of design-cycles being composed of a series of units (U), each unit (U) being defined as a group of design-cycles starting from and including one of the start design-cycles to but not including the next start-cycle, the total number (NU) of the units (U) being in the range of from 4 to 20, each unit (U) consists of at least one first-unit the number of which is 20 to 80% of said total number, at least one second-unit the number (R) of which is 20 to 80% of said total number, and optionally a third-unit the number (N) of which is 0 to 60% of said total number (NU), wherein the first unit is defined as including at least one pitch which is not less than a standard long pitch (PLa) and at least one pitch which is not more than a standard short pitch (PSa), the second unit is defined as including at least one pitch within one of the following two ranges, a range of not less than the standard long pitch (PLa) and a range of not more than the standard short pitch (PSa), but no pitch within the other range, the third unit is defined as all the pitches therein are more than the standard short pitch (PSa) and less than the standard long pitch (PLa), the standard long pitch (PLa) is the maximum pitch (PL) minus a length of 0.2 times a maximum pitch difference (MPD), the standard short pitch (PSa) is the minimum pitch (PS) plus a length of 0.2 times the maximum pitch difference (MPD) and the maximum pitch difference (MPD) is the maximum pitch (PL) minus the minimum pitch (PS).

2. A pneumatic tyre according to claim 1, characterised in that the difference (V) between any of the pitches and the next longer or shorter pitch is in the range of less than 6% of the average pitch (Pa).

3. A pneumatic tyre according to claim 1 or 2, characterised in that the number (NM) of variations in the pitches which variations are limited in the range of from 4 to 6 % of the average pitch (Pa) is set in the range of not more than 40% of the total number (NP-1) of the variations.

4. A pneumatic tyre according to claim 1, 2 or 3, characterised in that said units include a plurality of third-units, and the third units do not adjoin each other in the tyre circumferential direction.

5. A pneumatic tyre according to claim 1, 2, 3 or 4, characterised in that all the units are different from each other in respect of the sequence of the pitches therein.

6. A pneumatic tyre according to claim 1, 2, 3, 4 or 5, characterised in that the difference (G) between pitches which adjoin each other in the tyre circumferential direction is not more than 25% of the average pitch (Pa).

7. A pneumatic tyre according to any of claims 1-6, characterised in that said tread portion is provided with at least one row of blocks which are circumferentially divided by axial grooves, and each said design-cycle is defined by one of the blocks and one of the axial grooves adjacent thereto on one side thereof.

Fig. 1

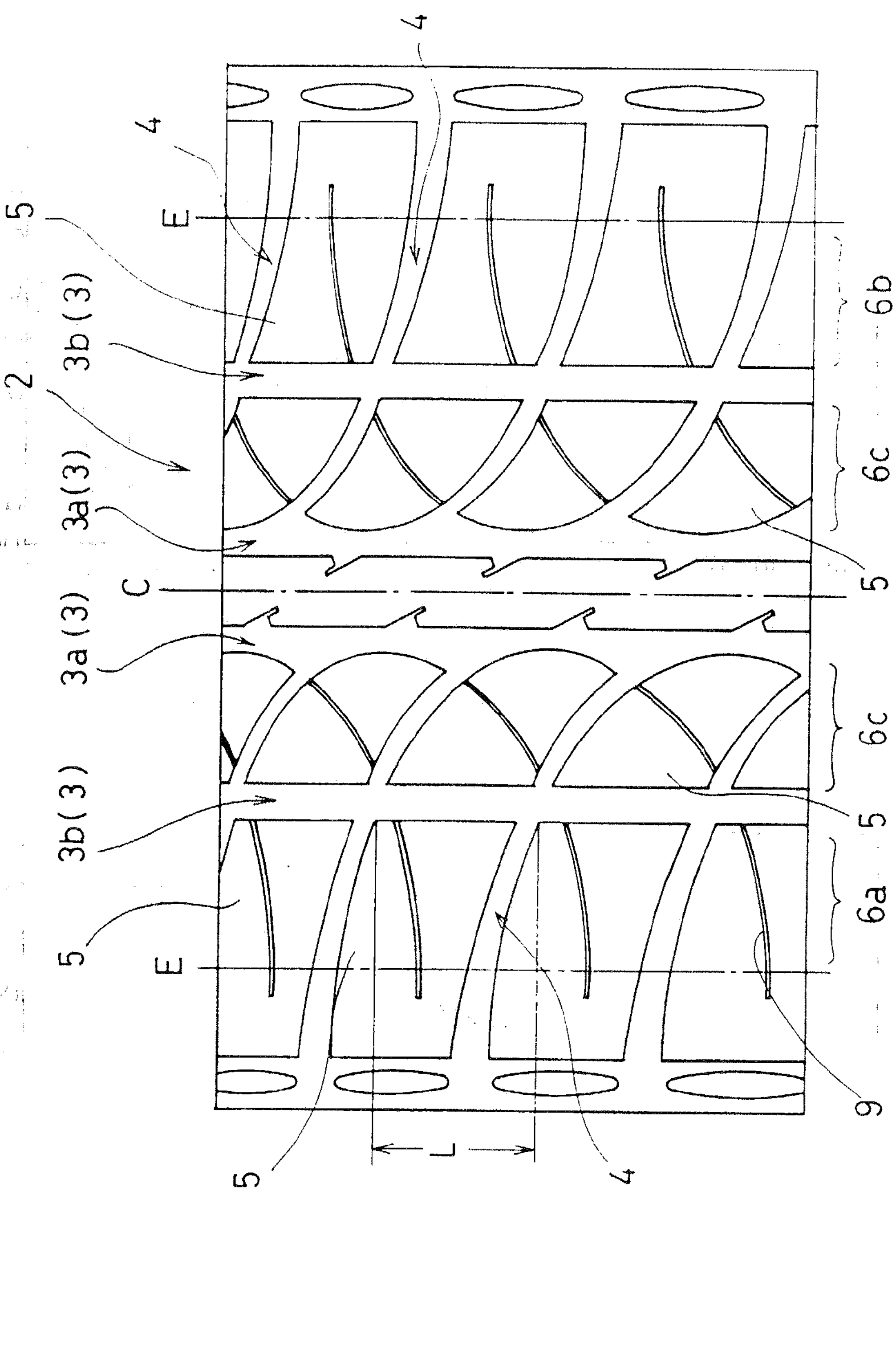
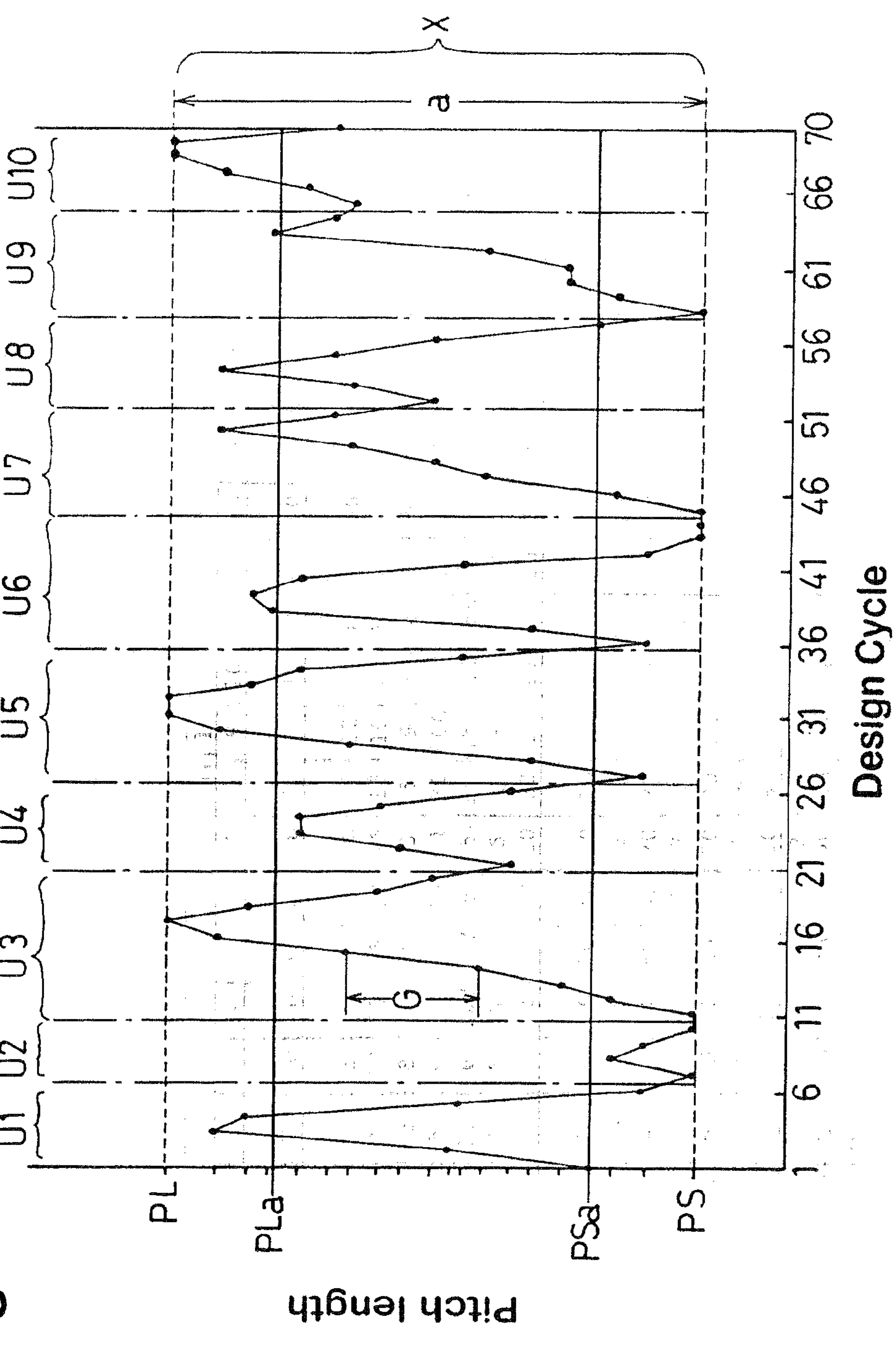


Fig. 2



	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
First Unit	○		○		○	○	○	○	○	
Second Unit		○								○
Third Unit				○						

Fig. 3

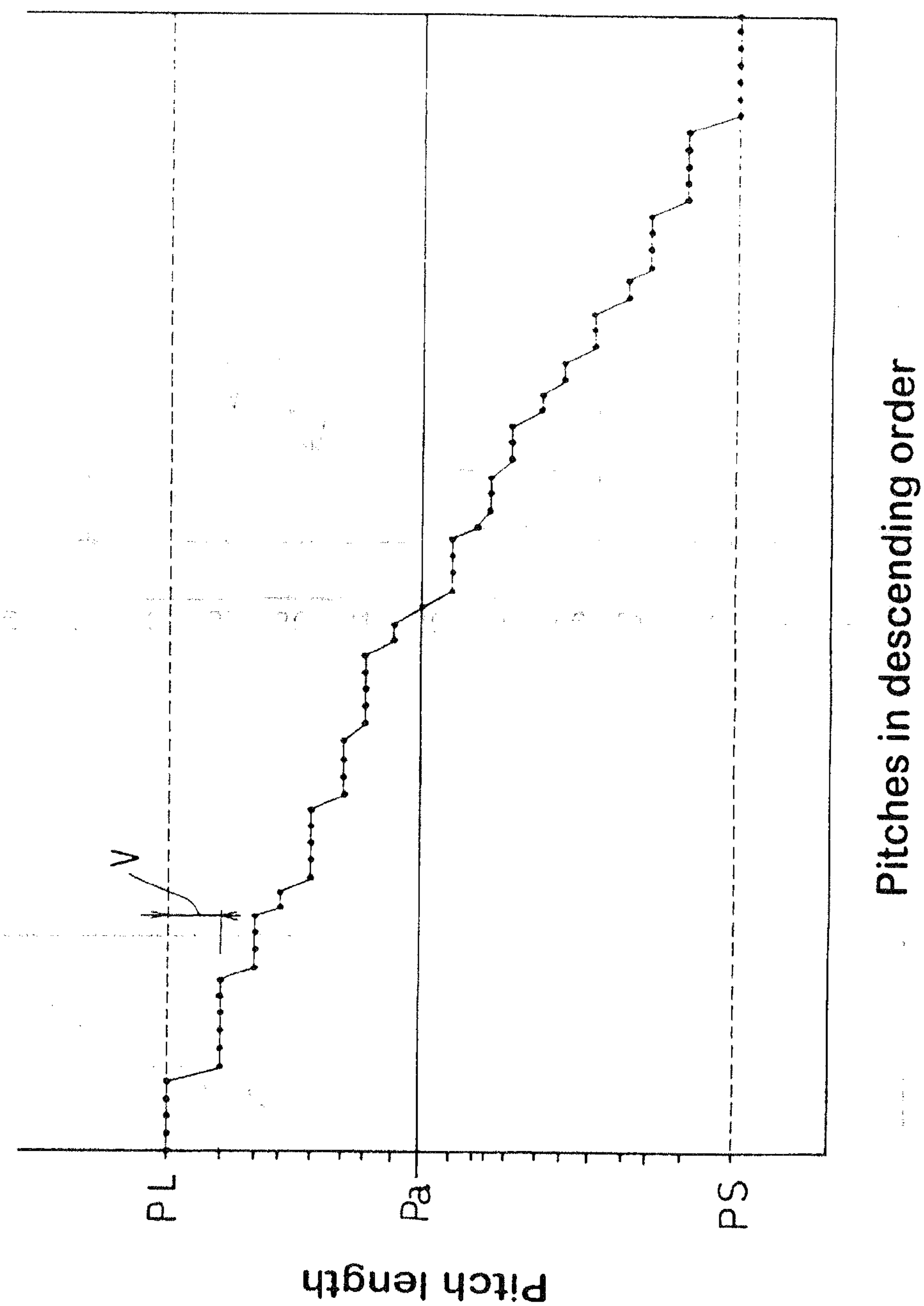
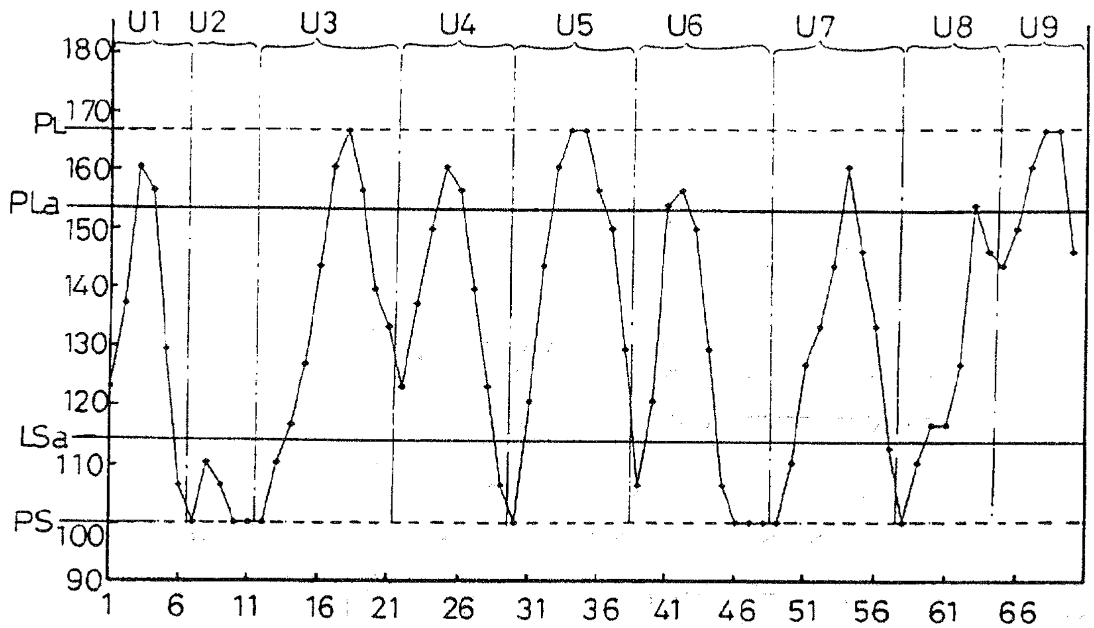


Fig. 4 Ex. 1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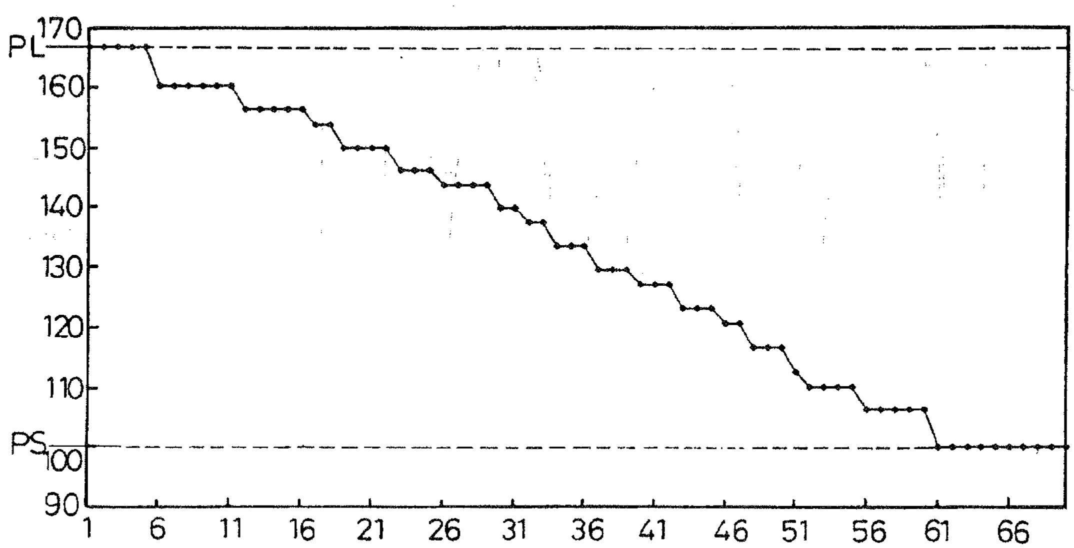
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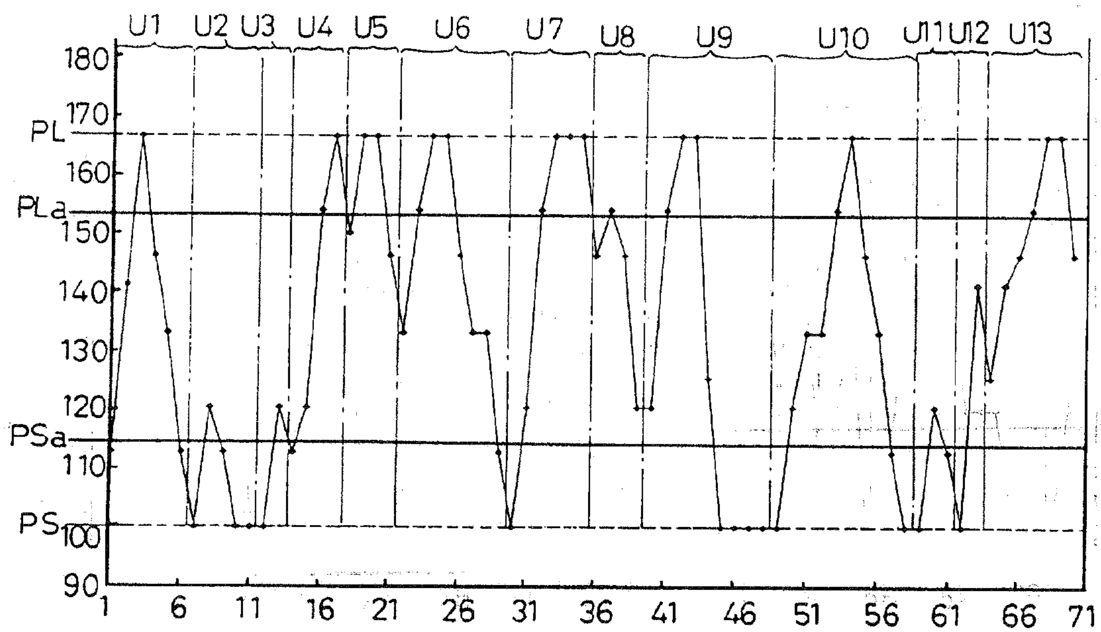
Fig. 5 Ex. 2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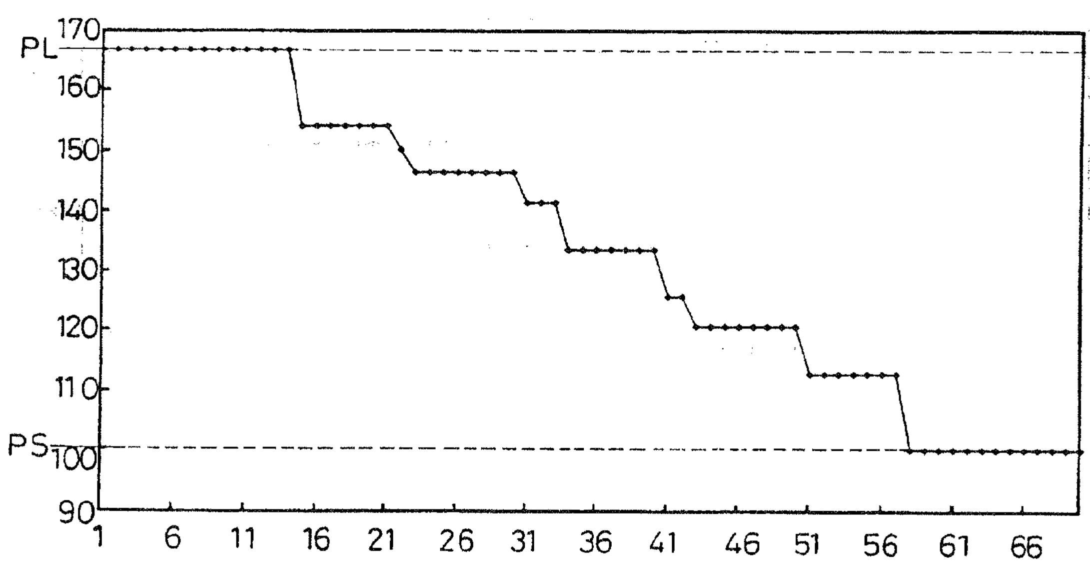
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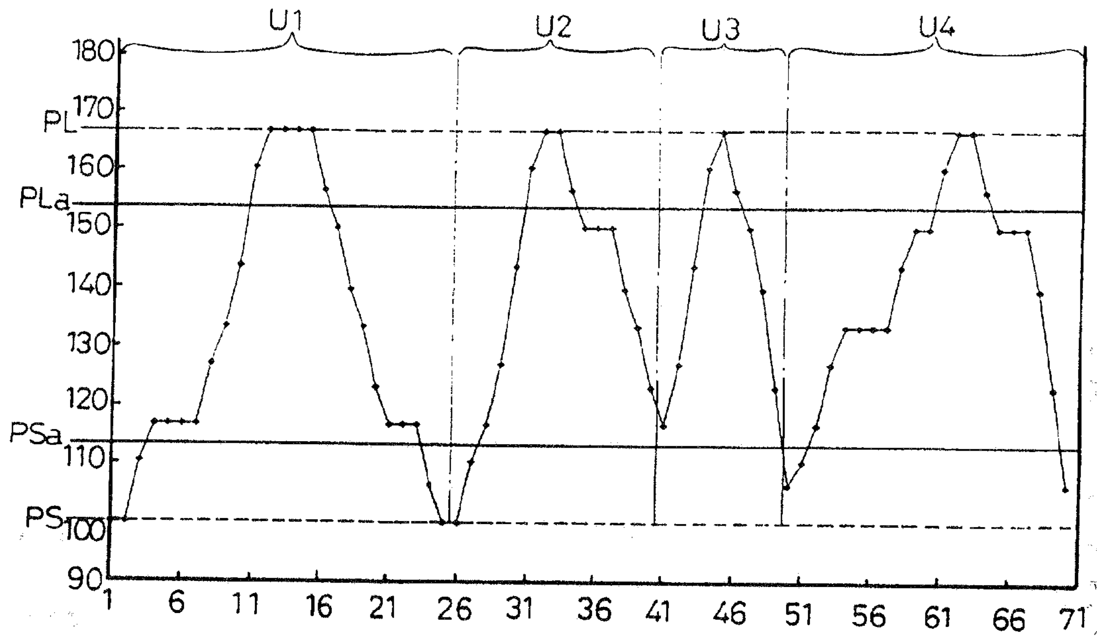
Fig. 6 Ex. 3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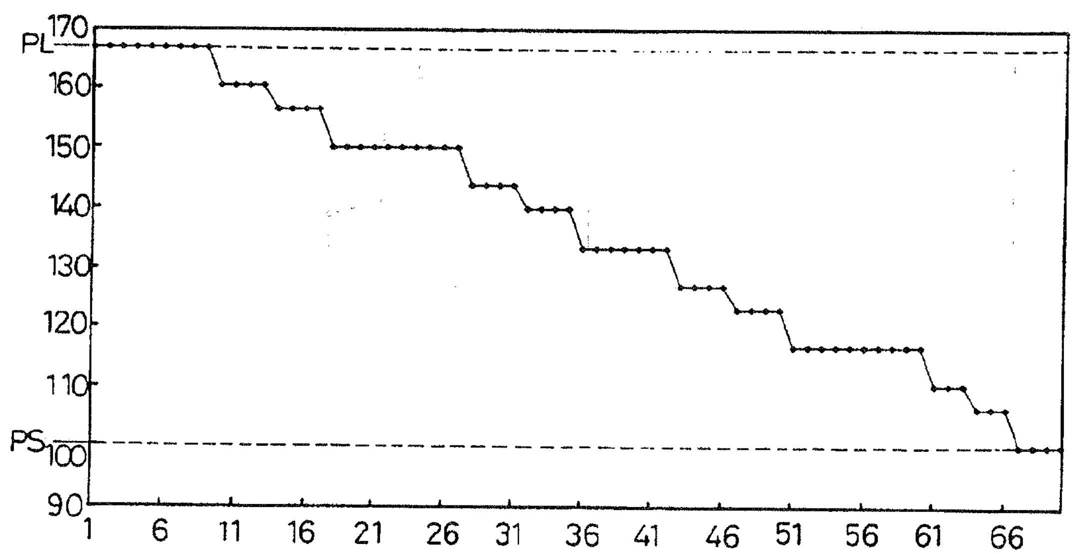
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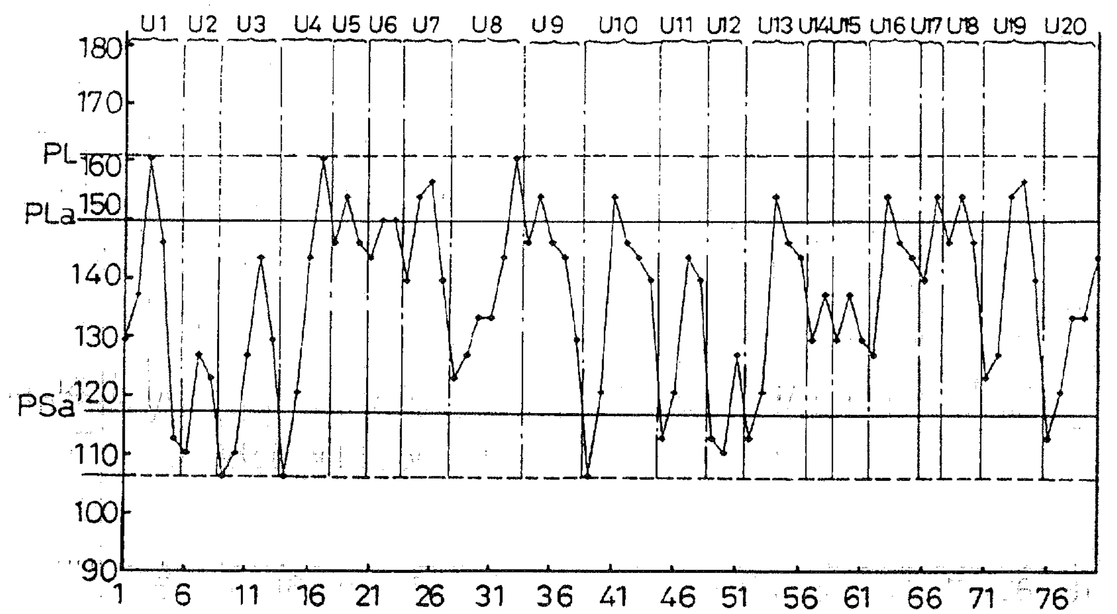
Fig. 7 Ex. 4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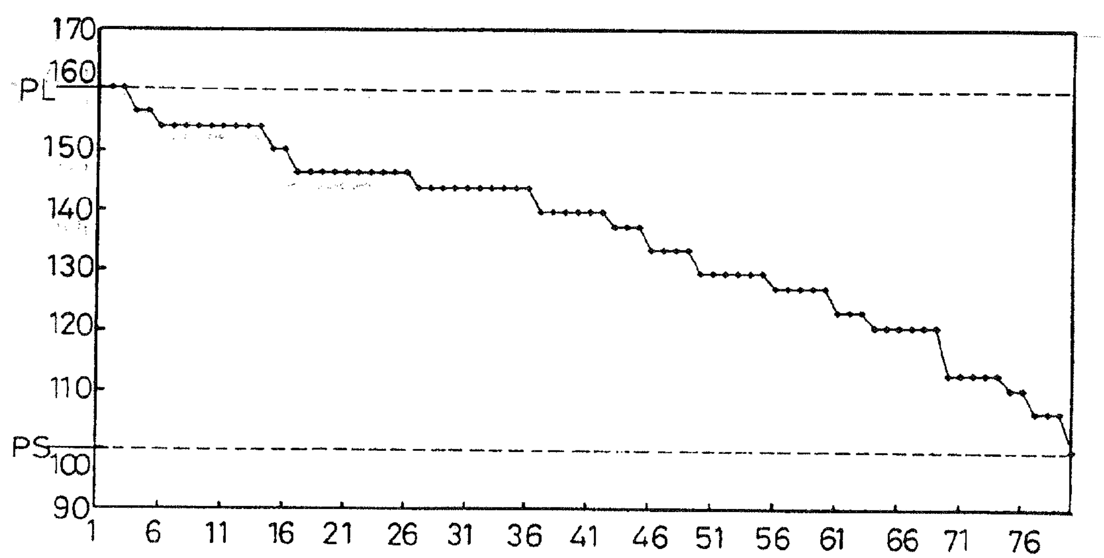
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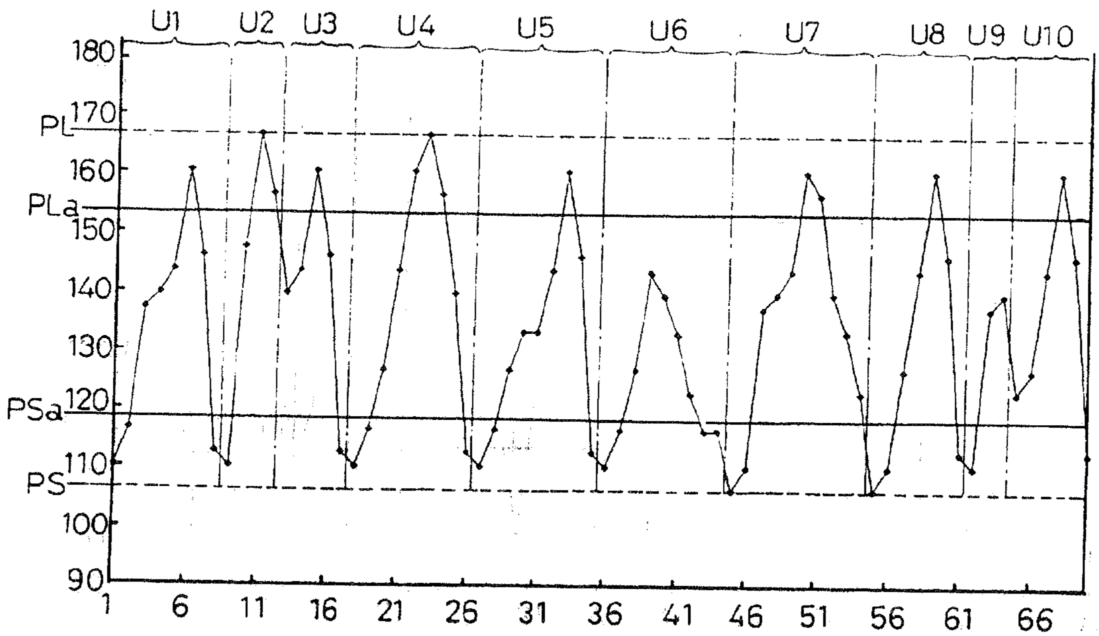
Fig. 8 Ex. 5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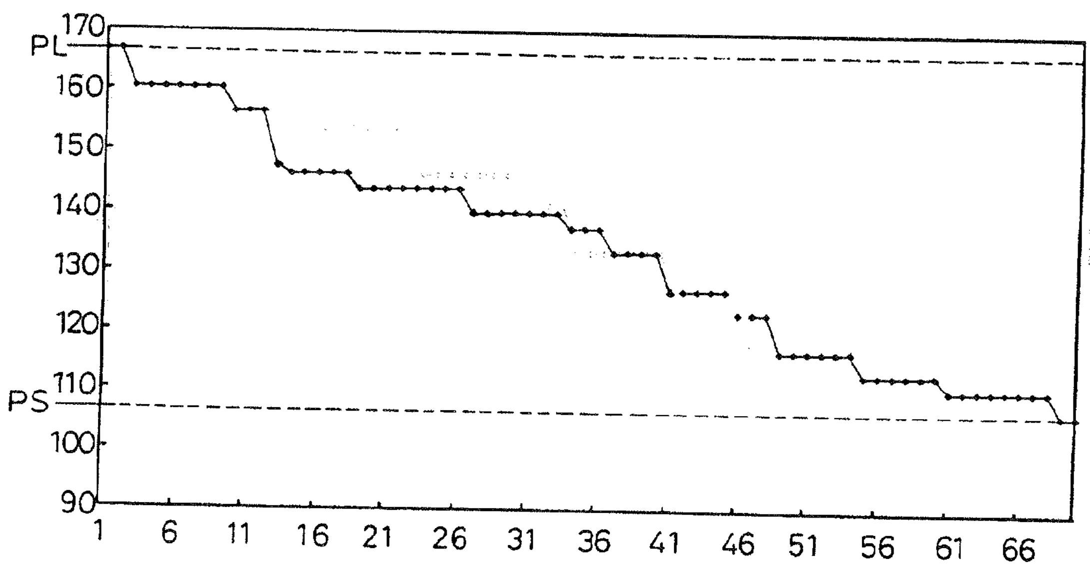
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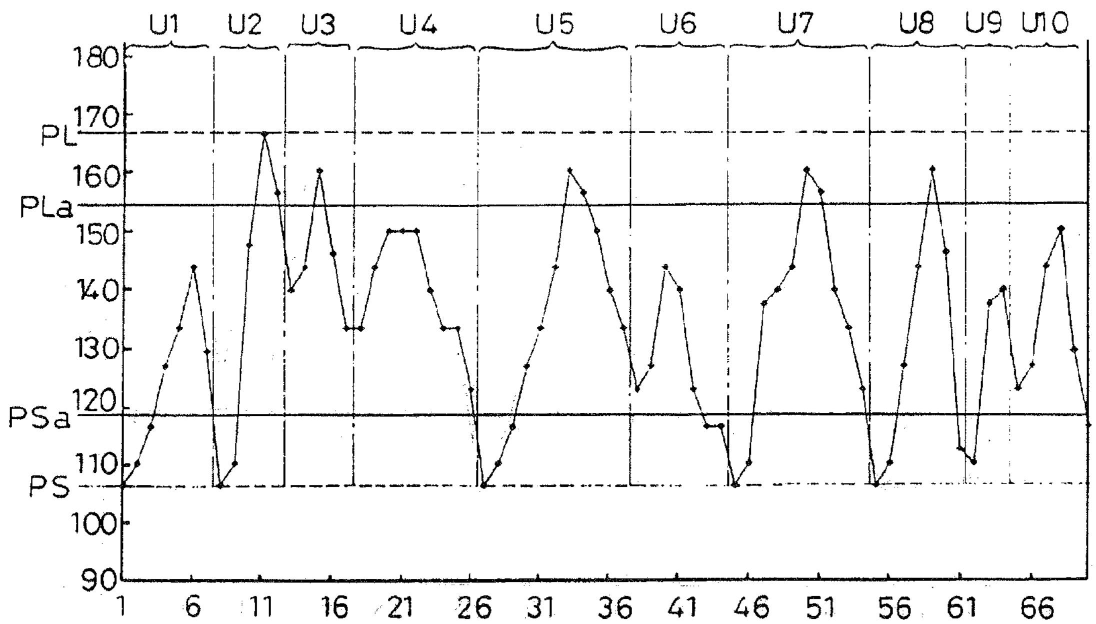
Fig. 9 Ex. 6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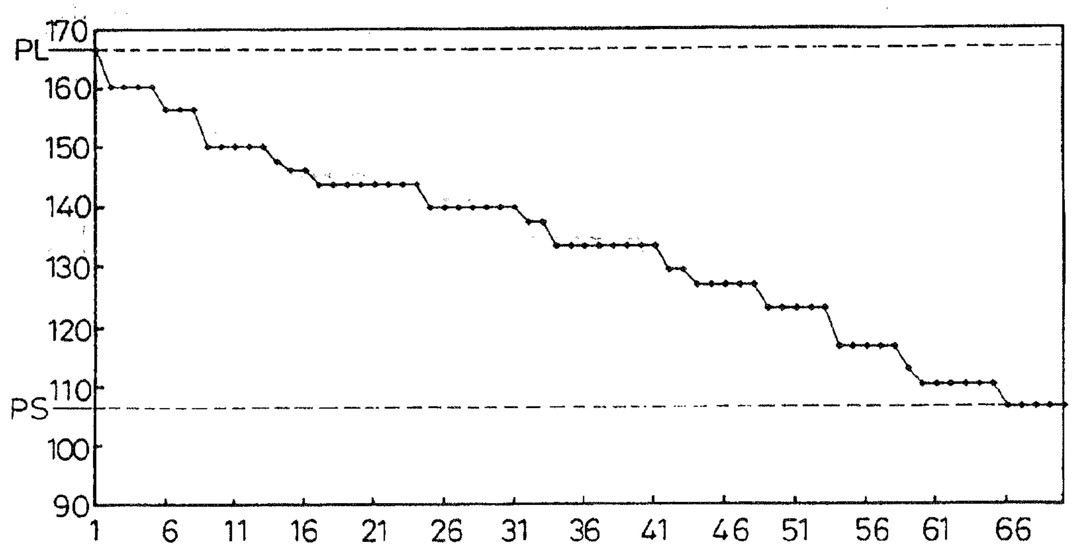
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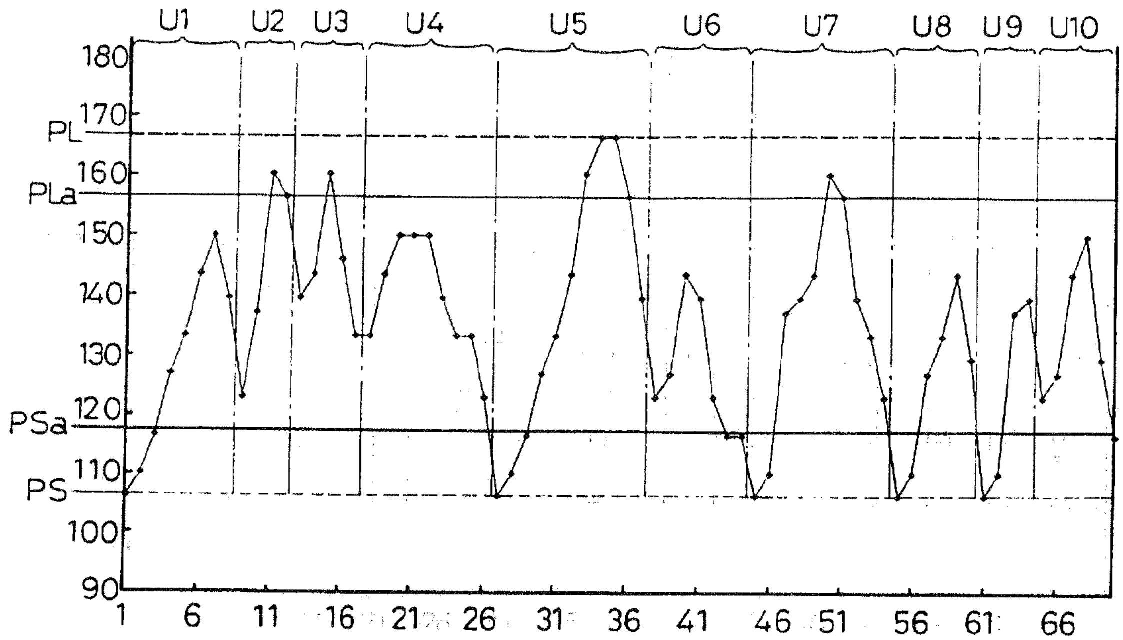
Fig. 10 Ex. 7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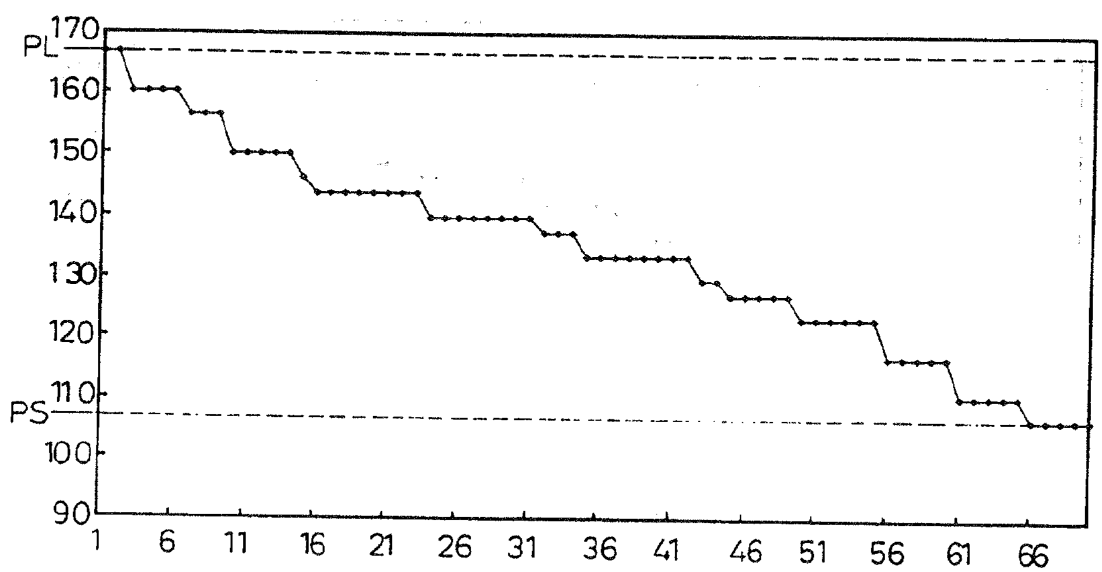
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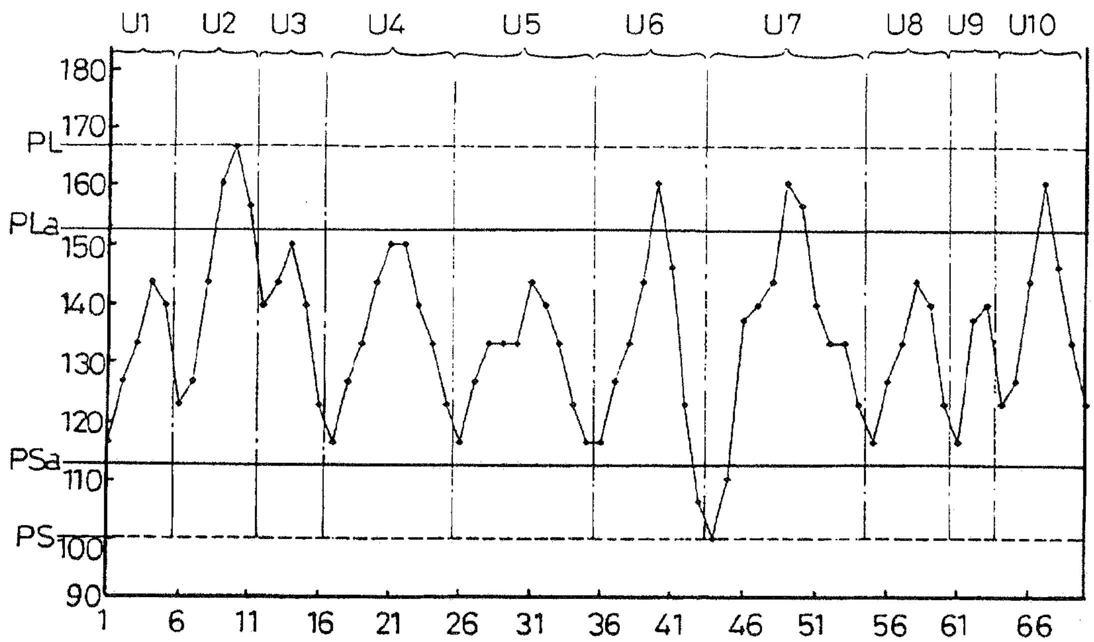
Fig. 11 Ex. 8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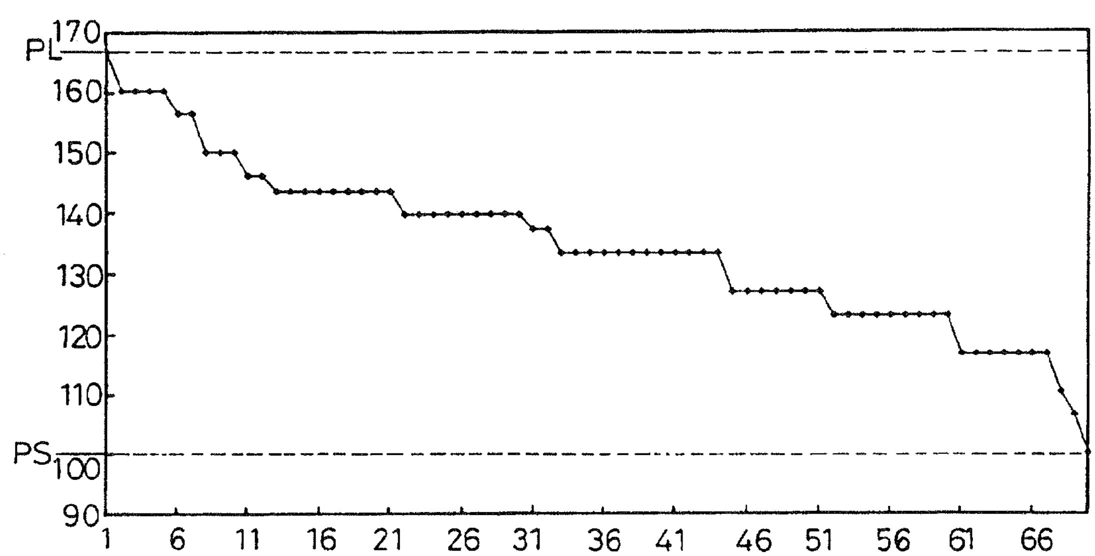
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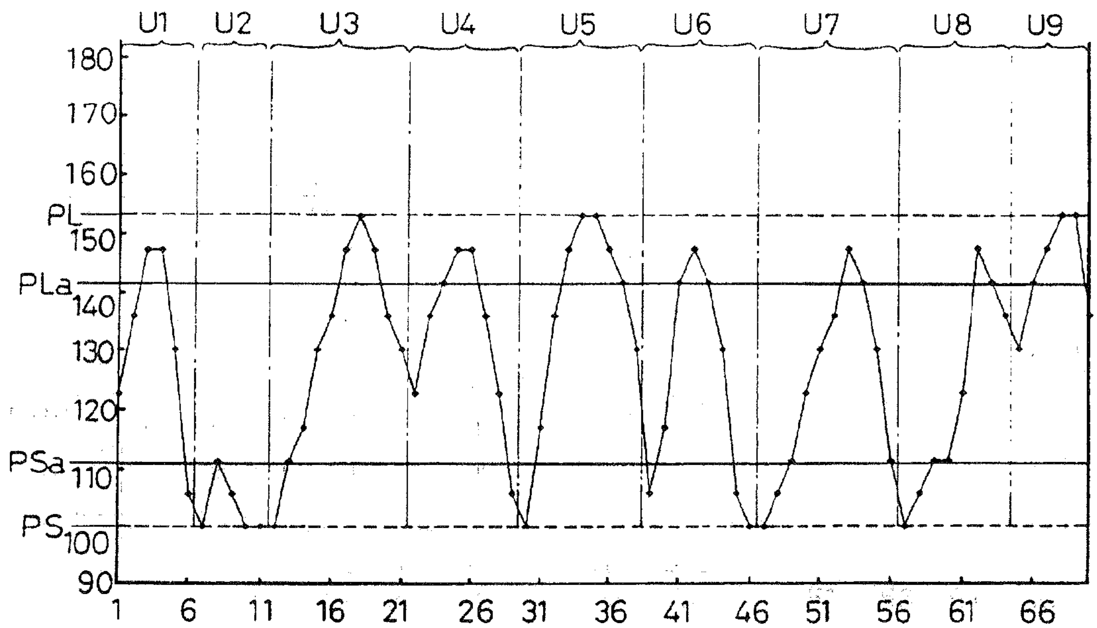
Fig. 12 Ex. 9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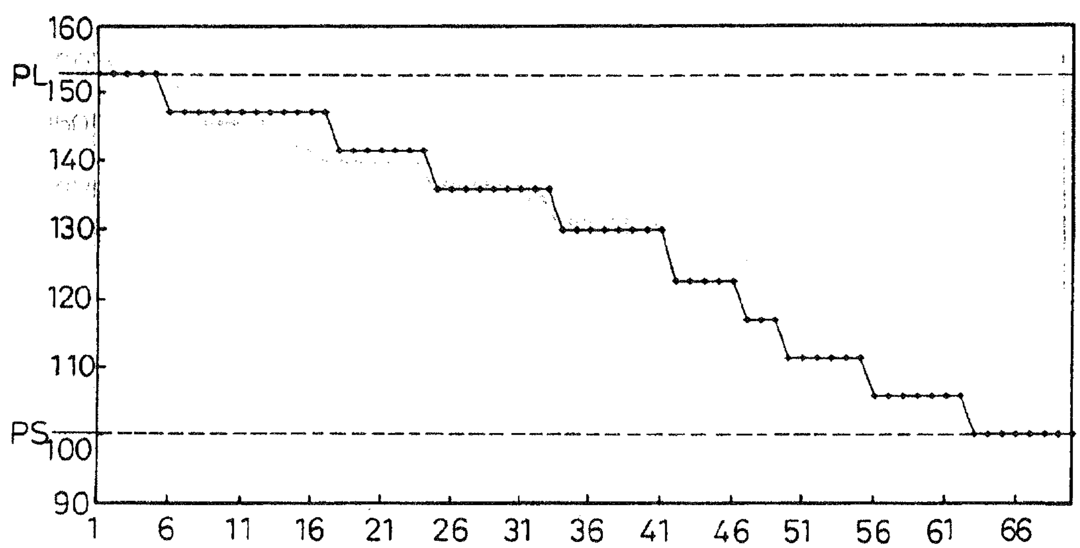
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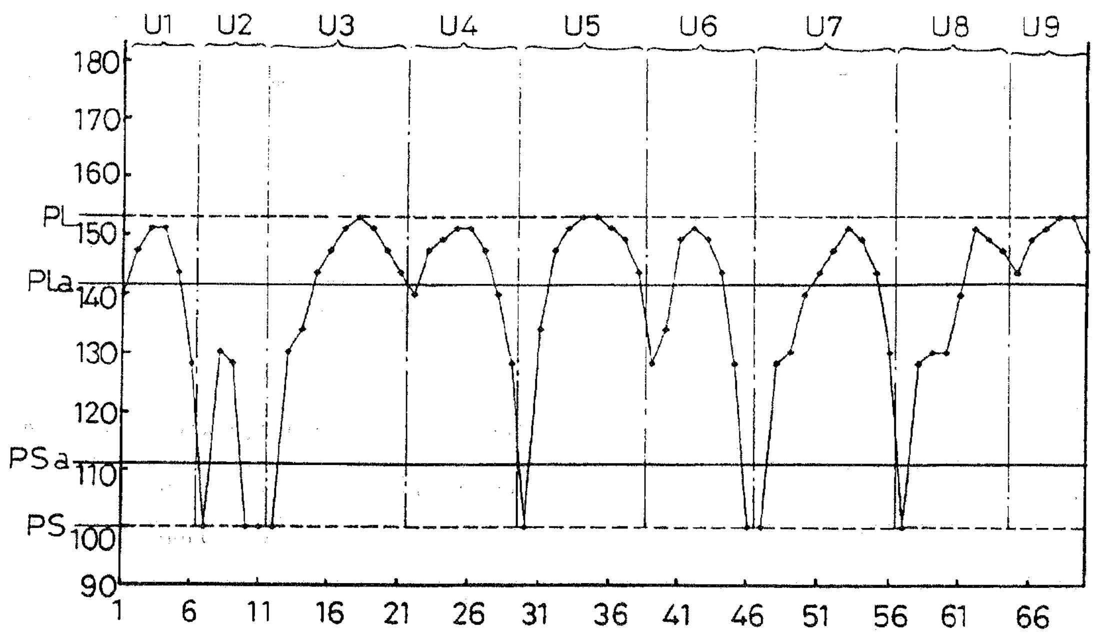
Fig. 13 Ex. 10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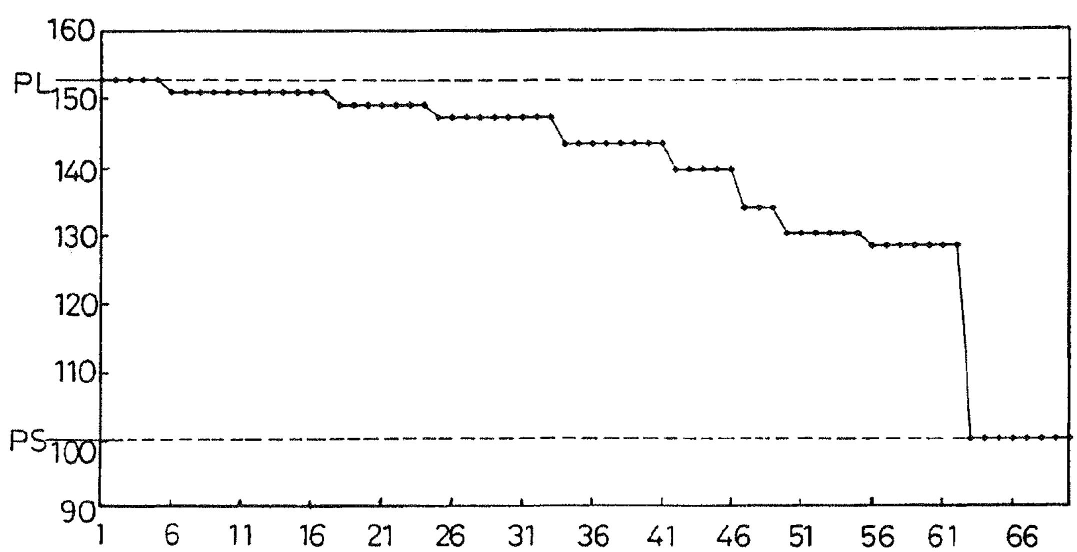
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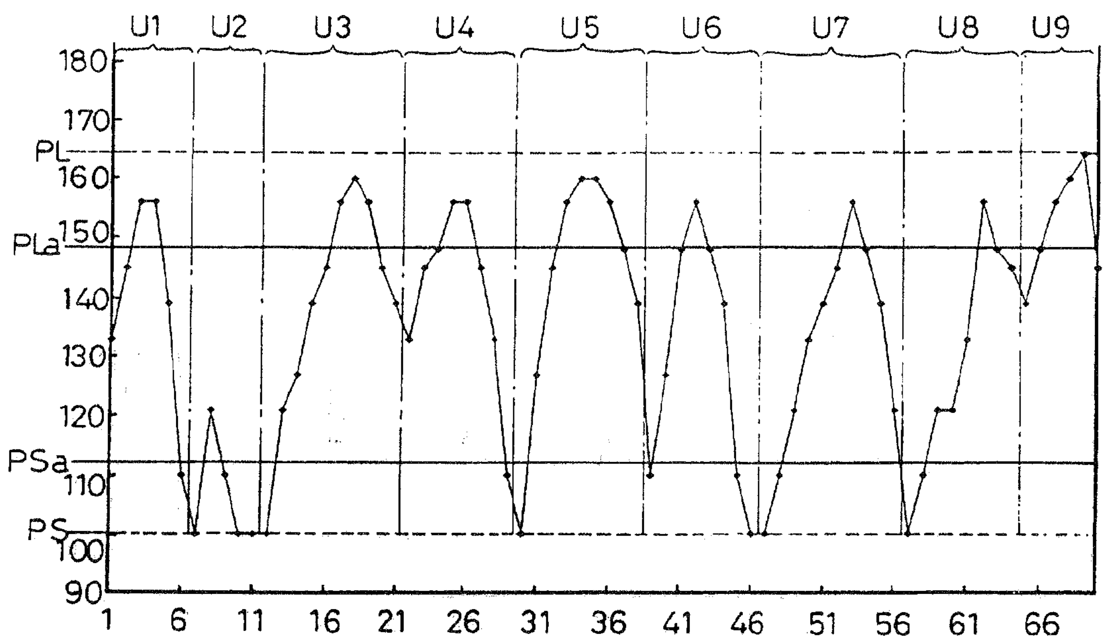
Fig. 14 Ex. 11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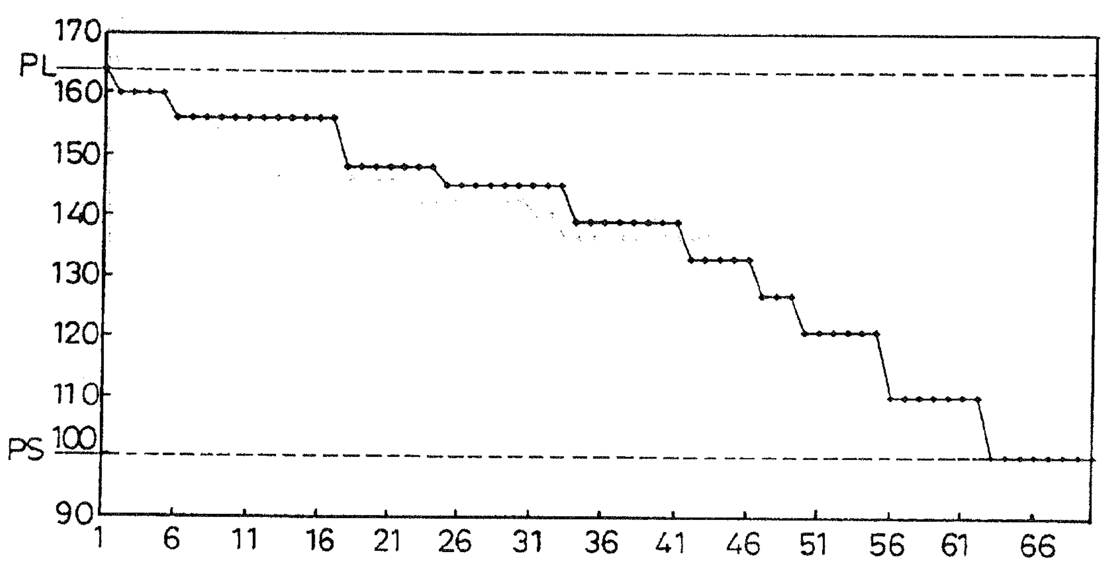
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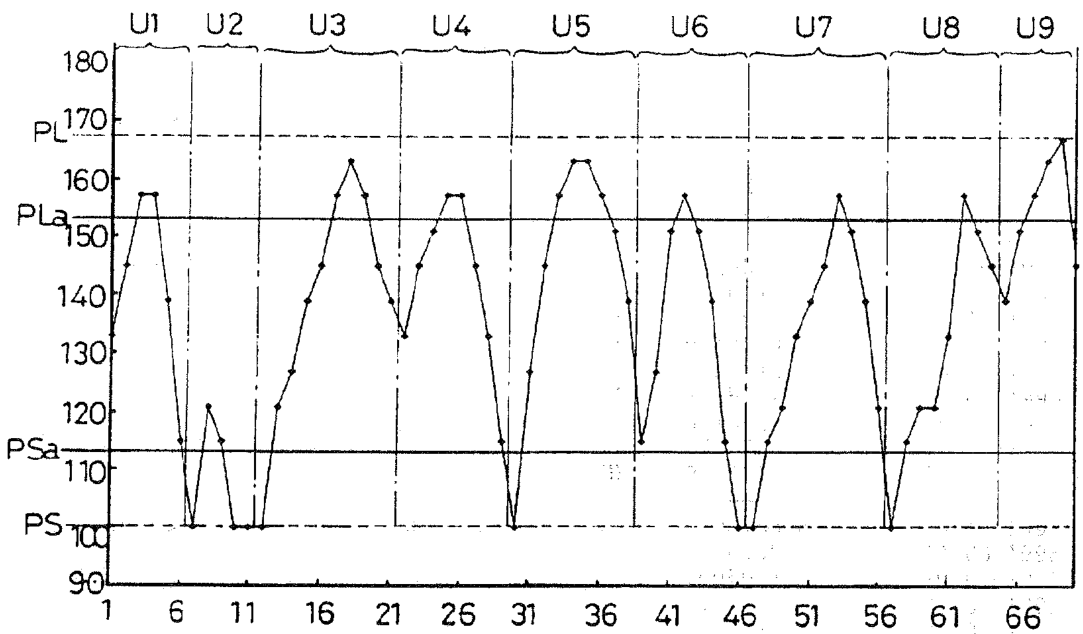
Fig. 15 Ex. 12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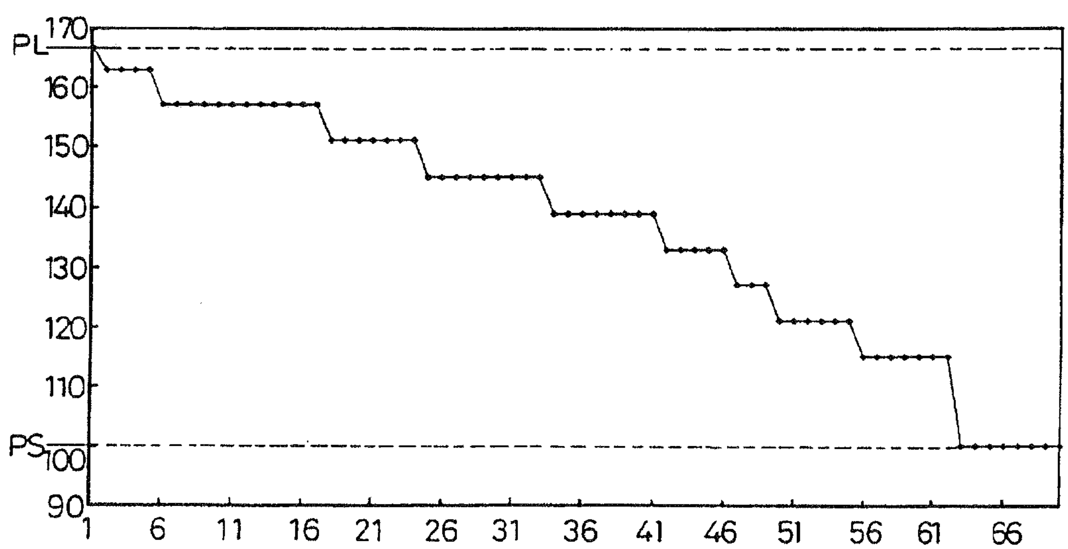
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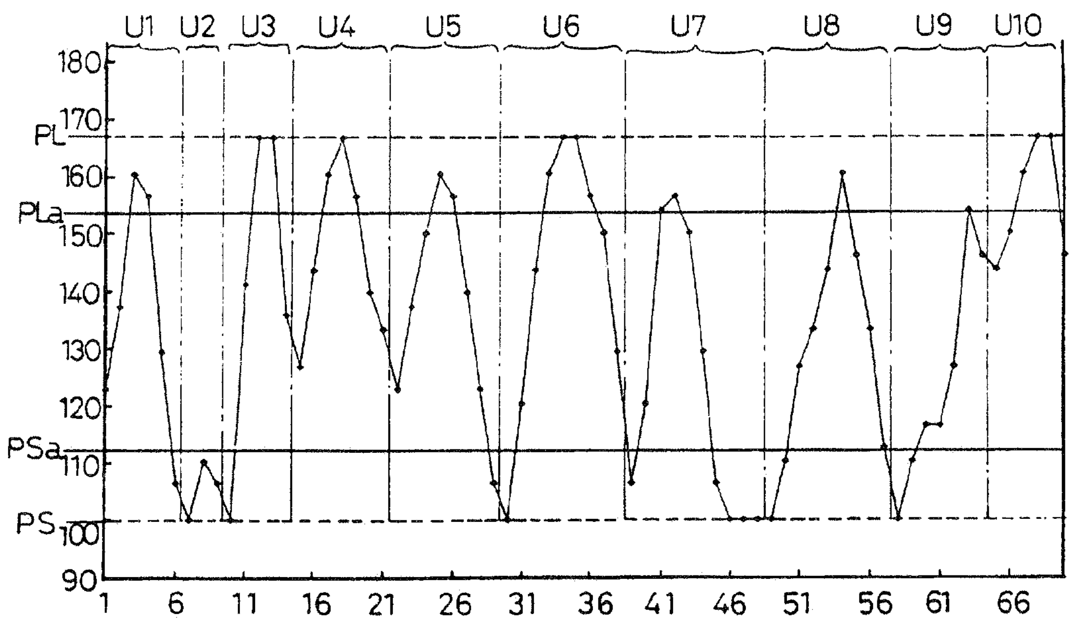
Fig. 16 Ex. 13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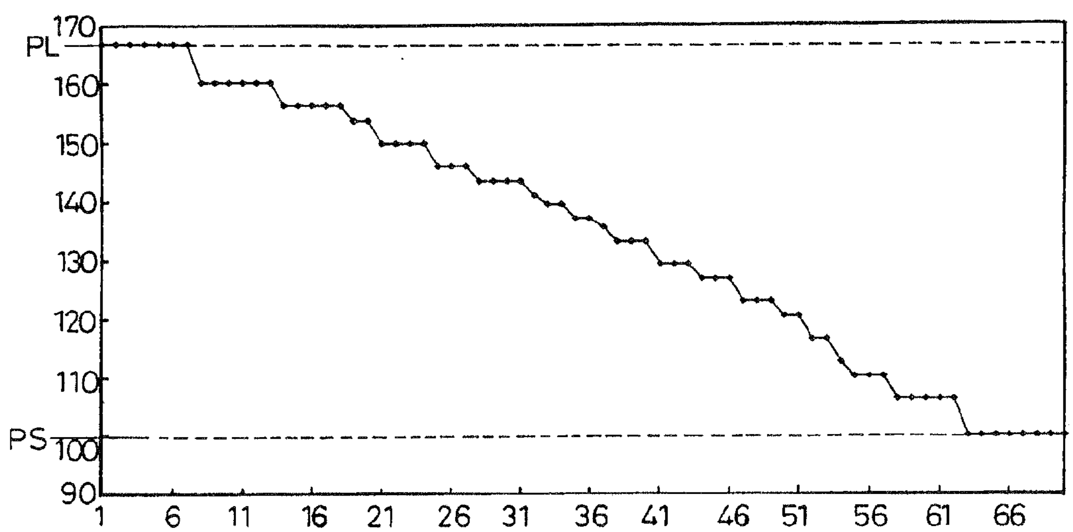
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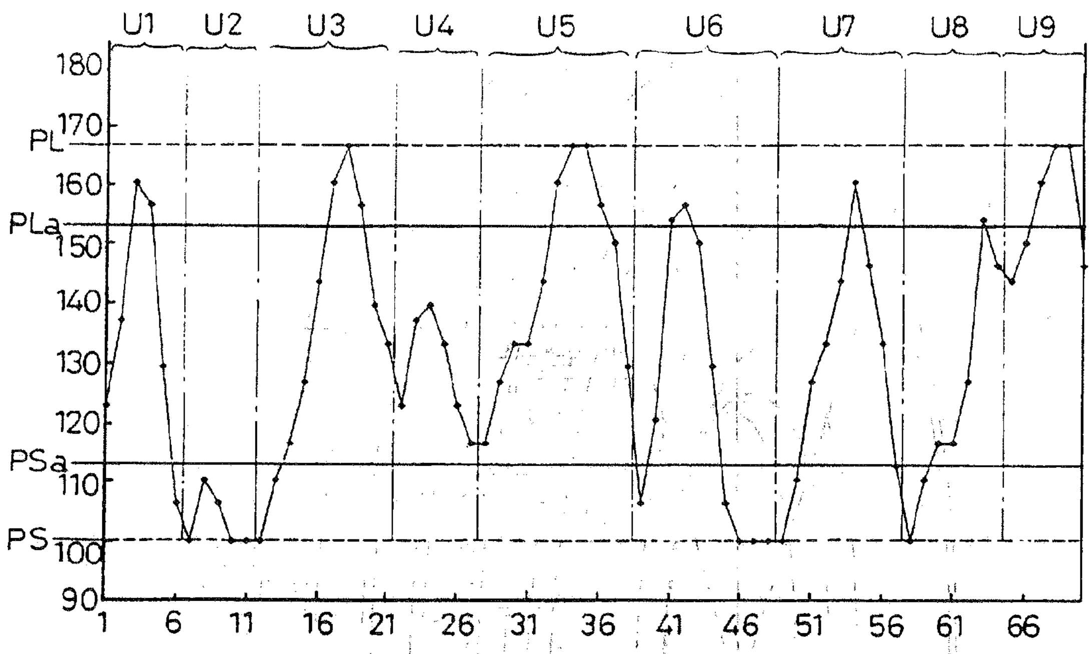
Fig. 17 Ex. 14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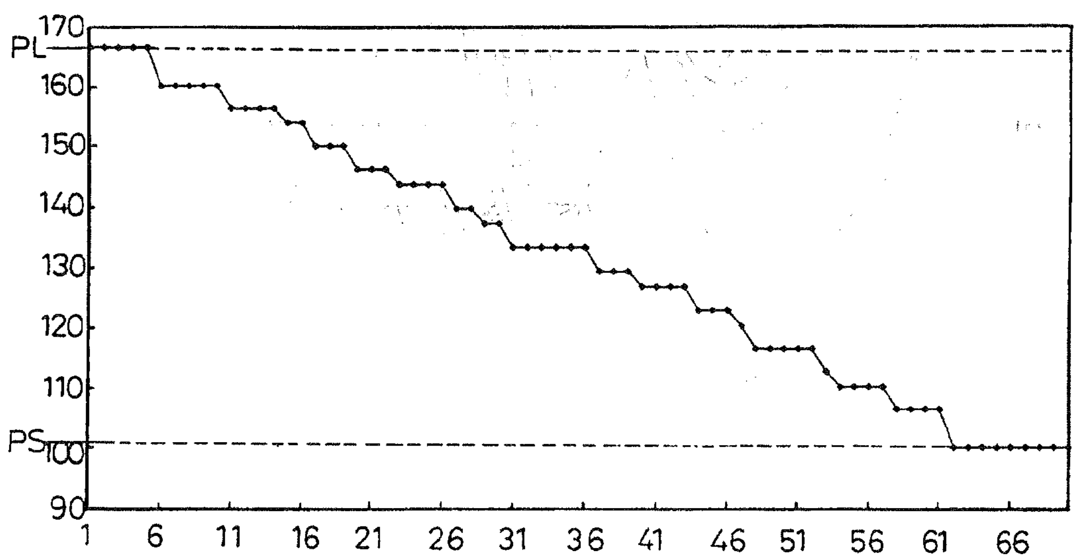
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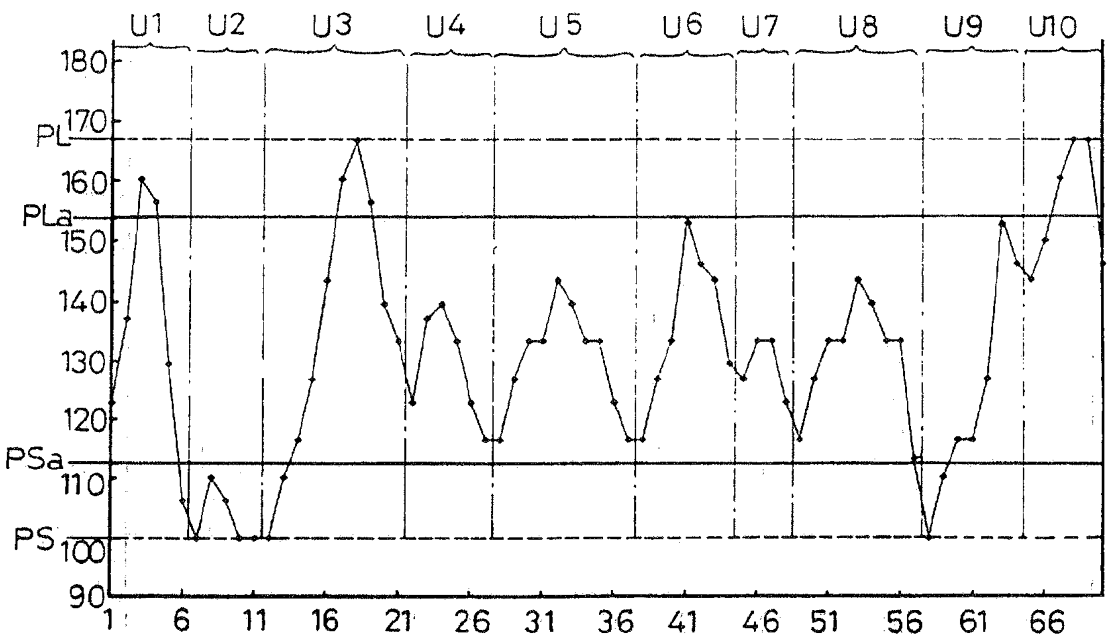
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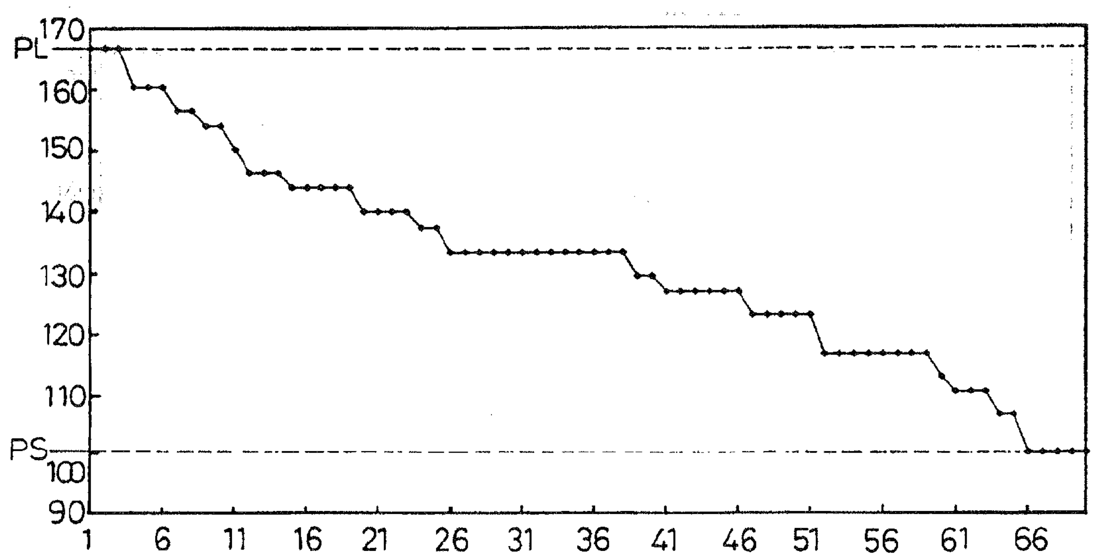
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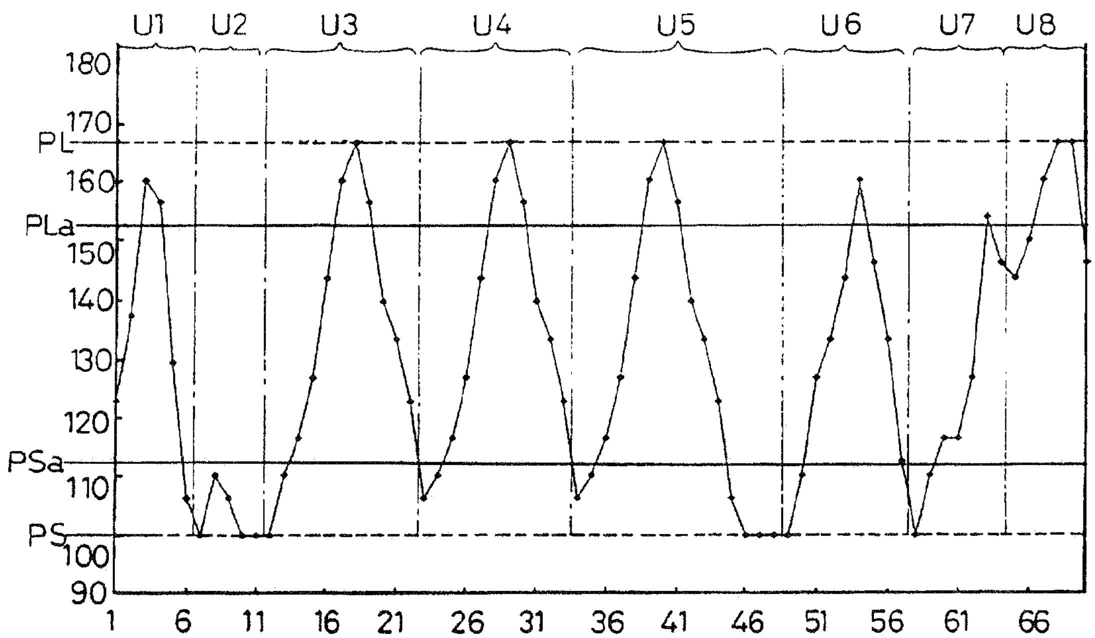
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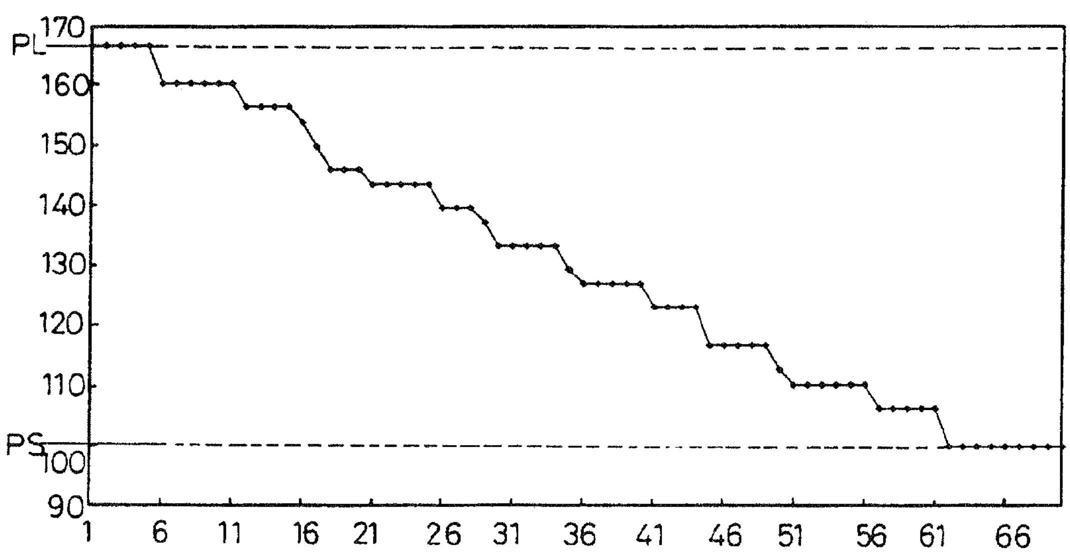
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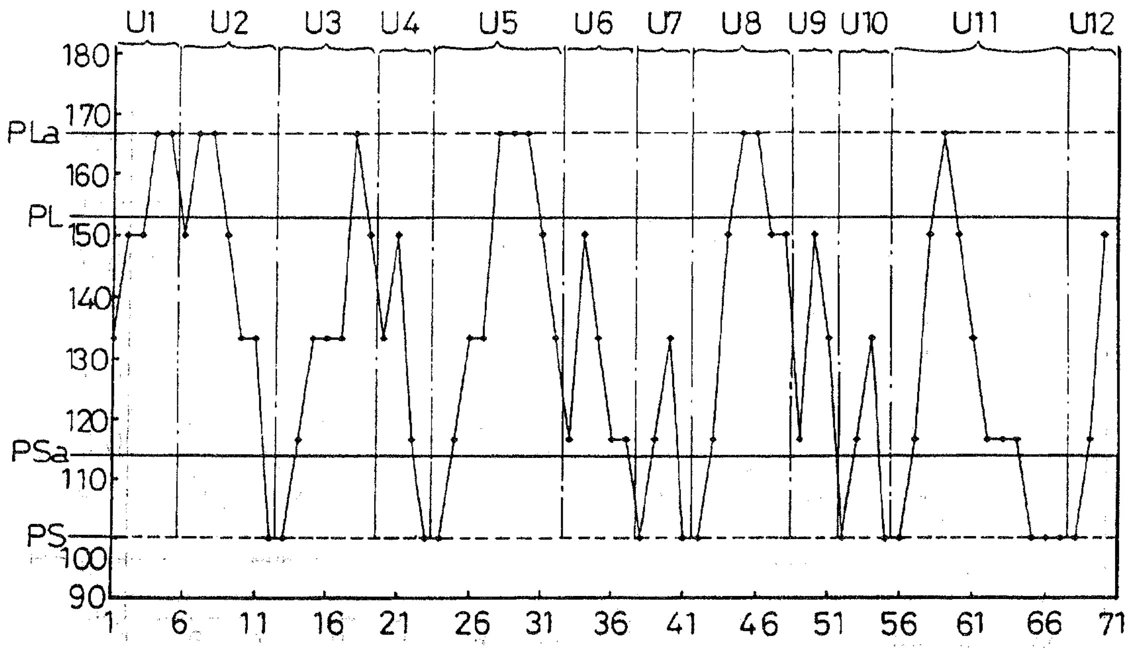
Fig. 20 Ref. 1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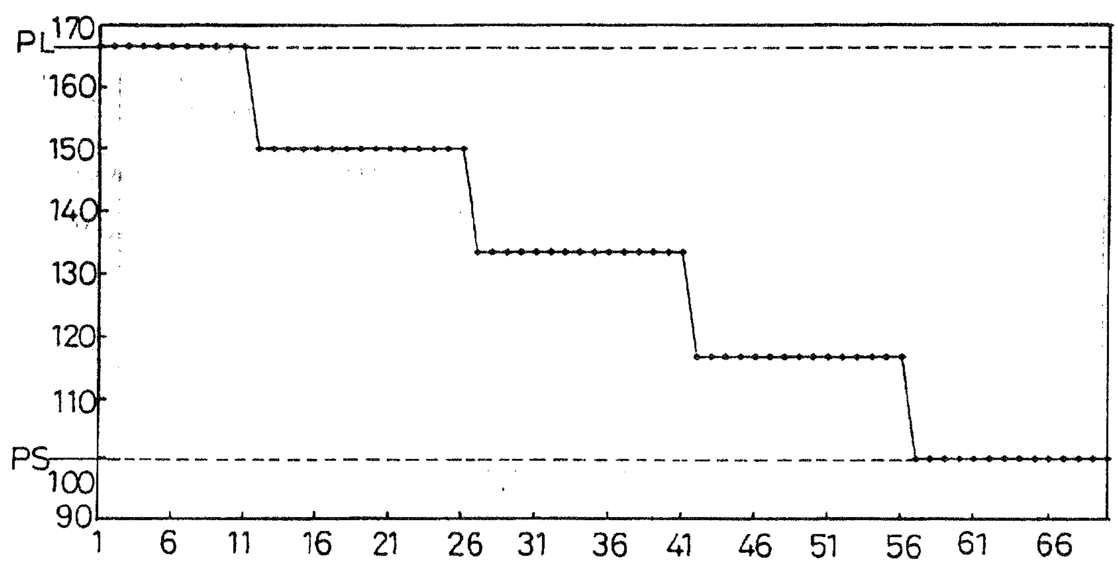
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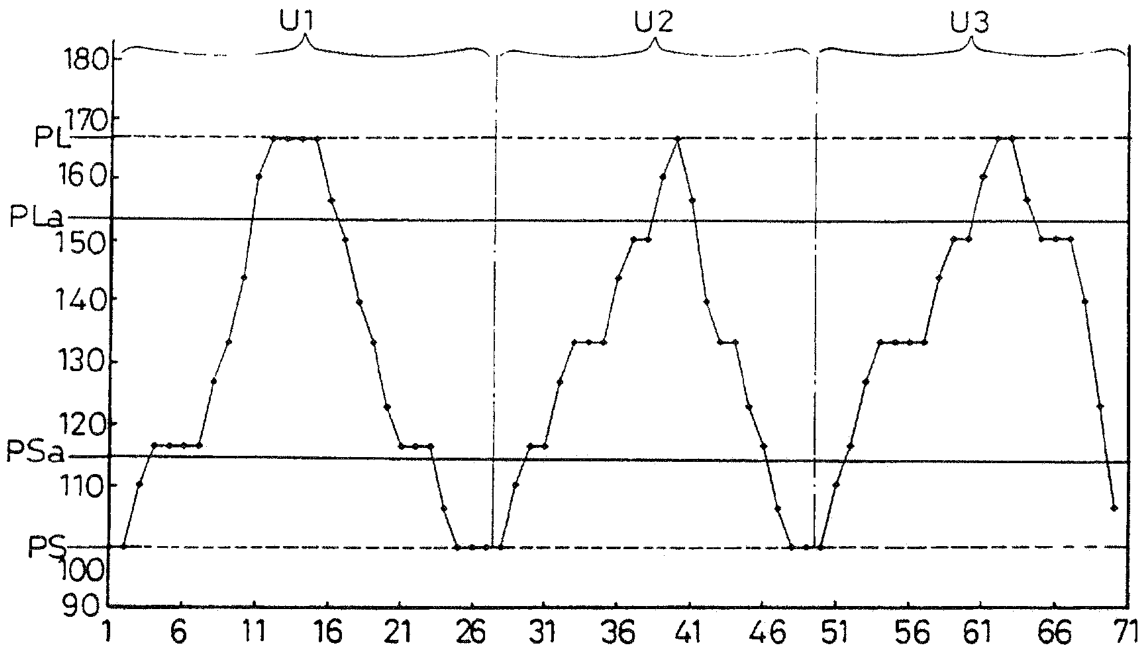
Fig. 21 Ref. 2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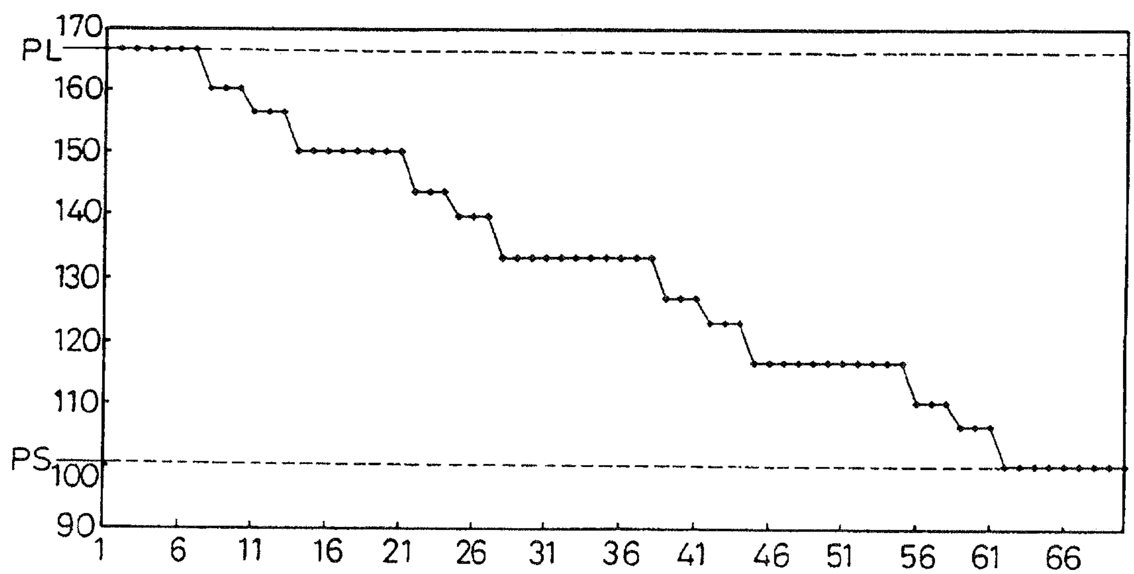
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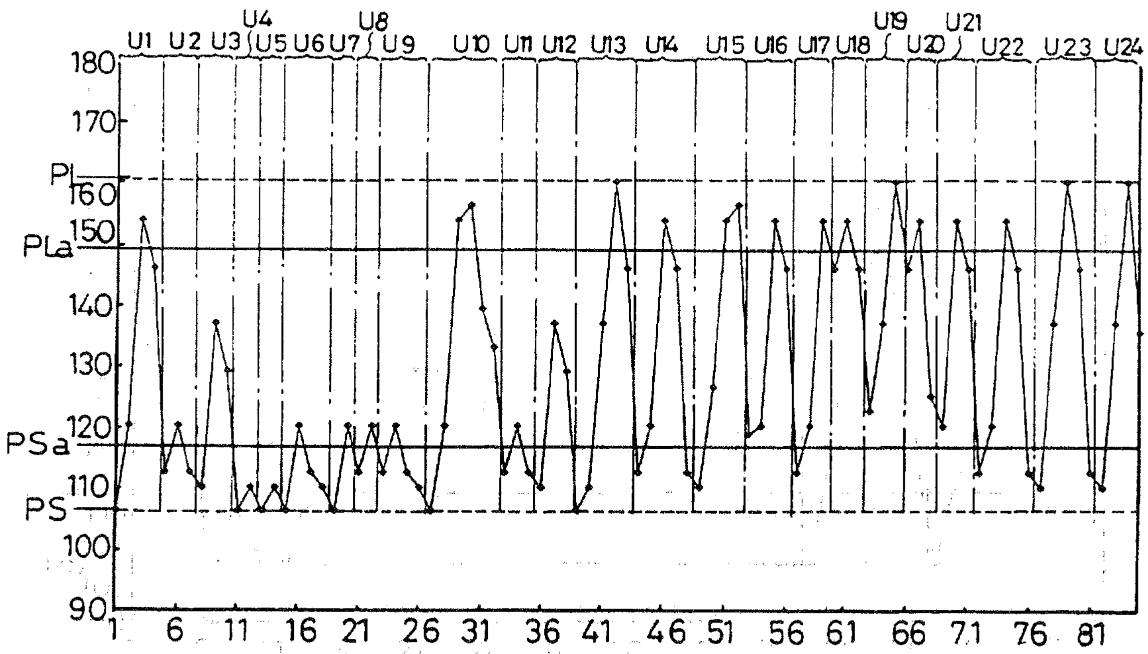
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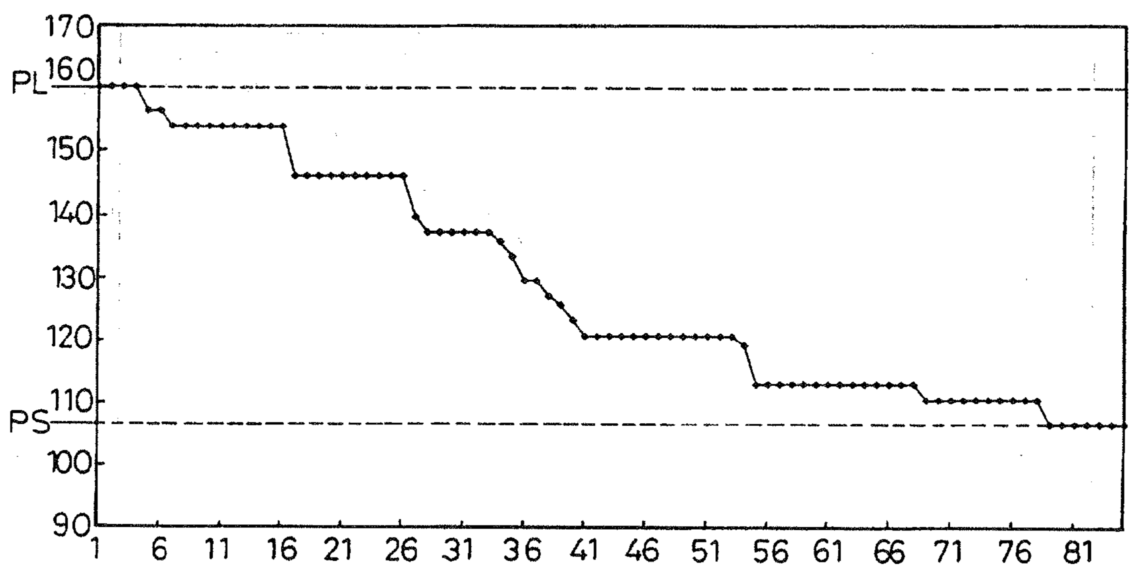
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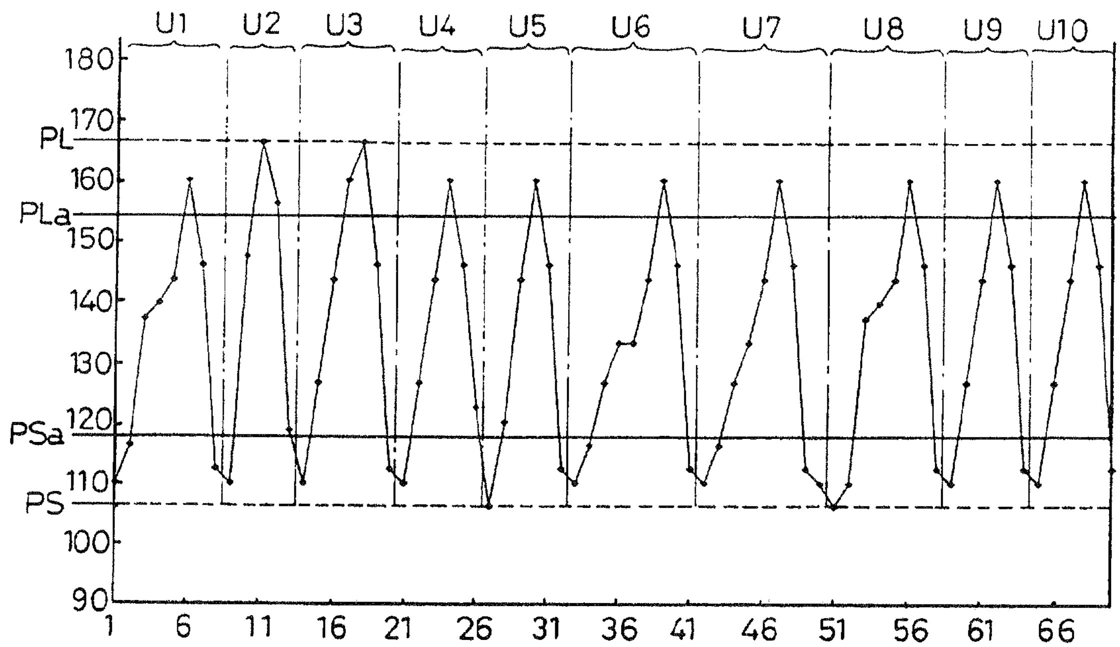
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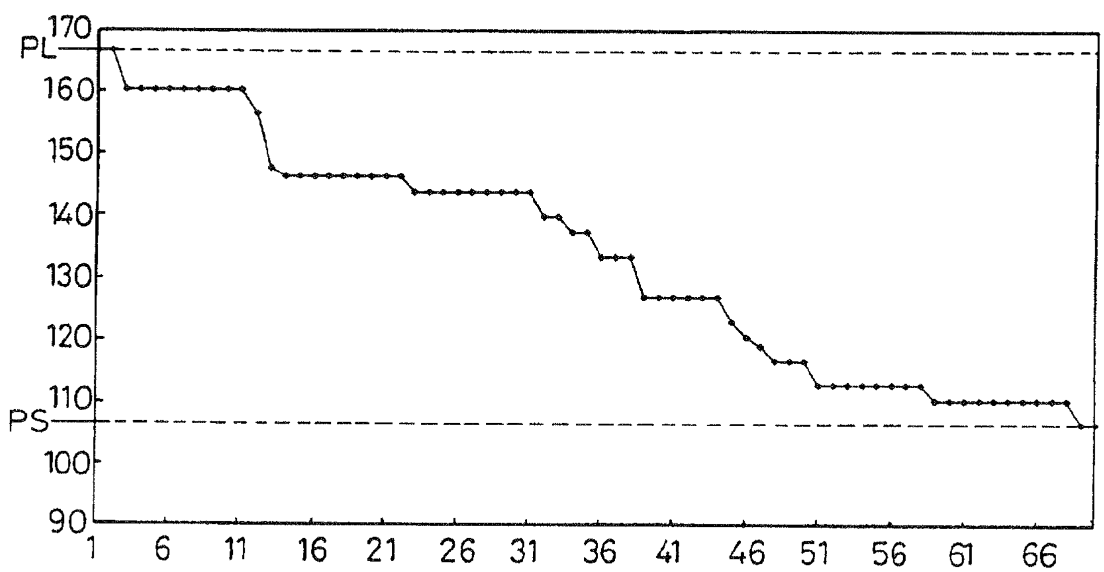
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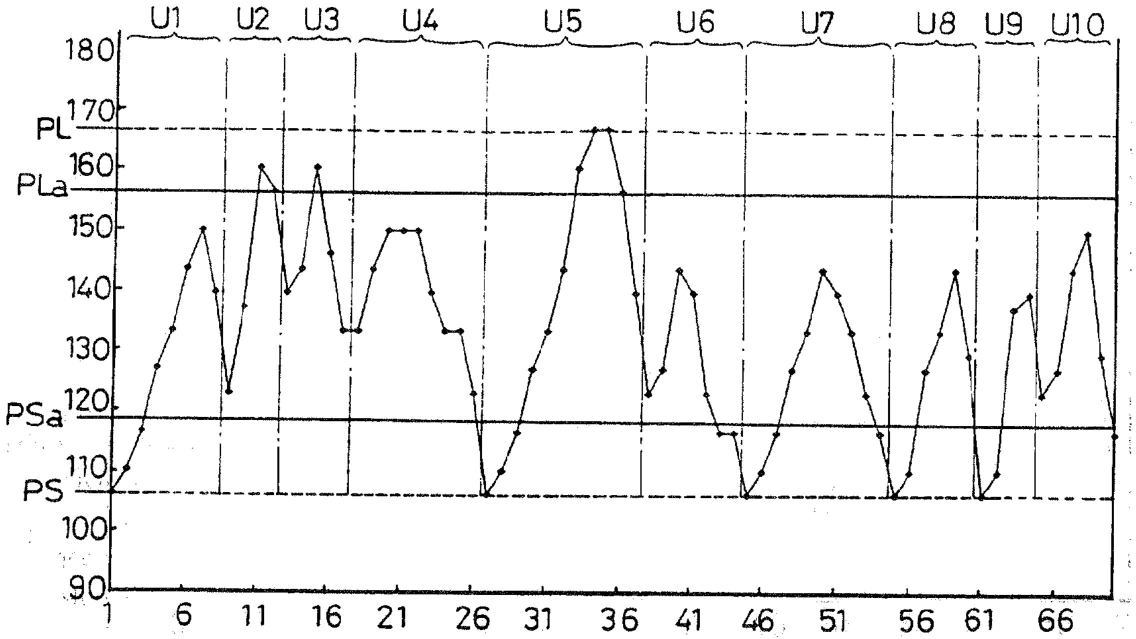
Fig. 24 Ref. 5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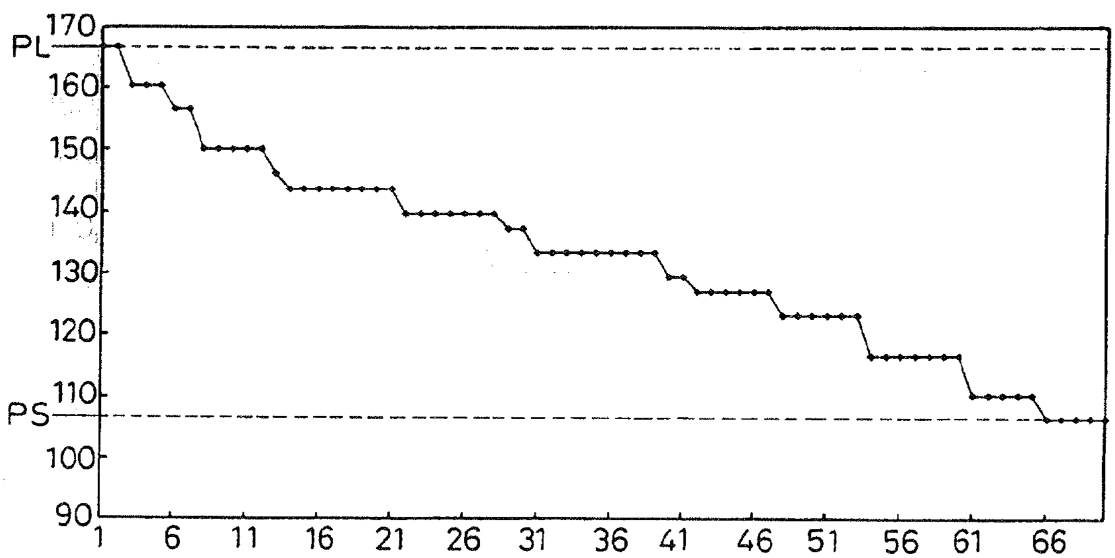
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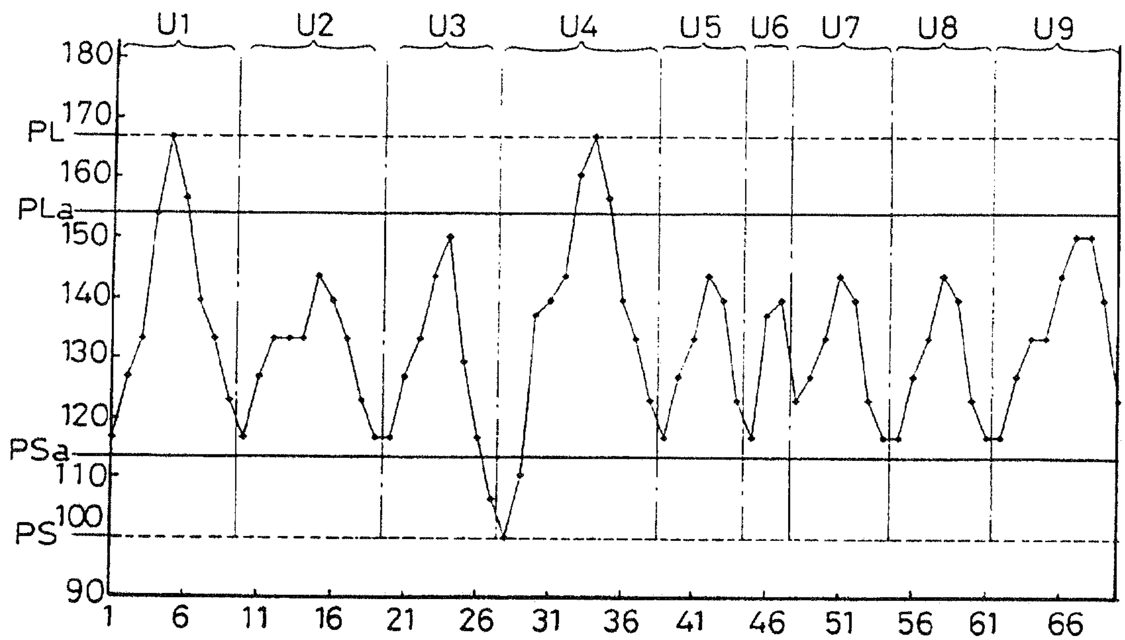
Fig. 25 Ref. 6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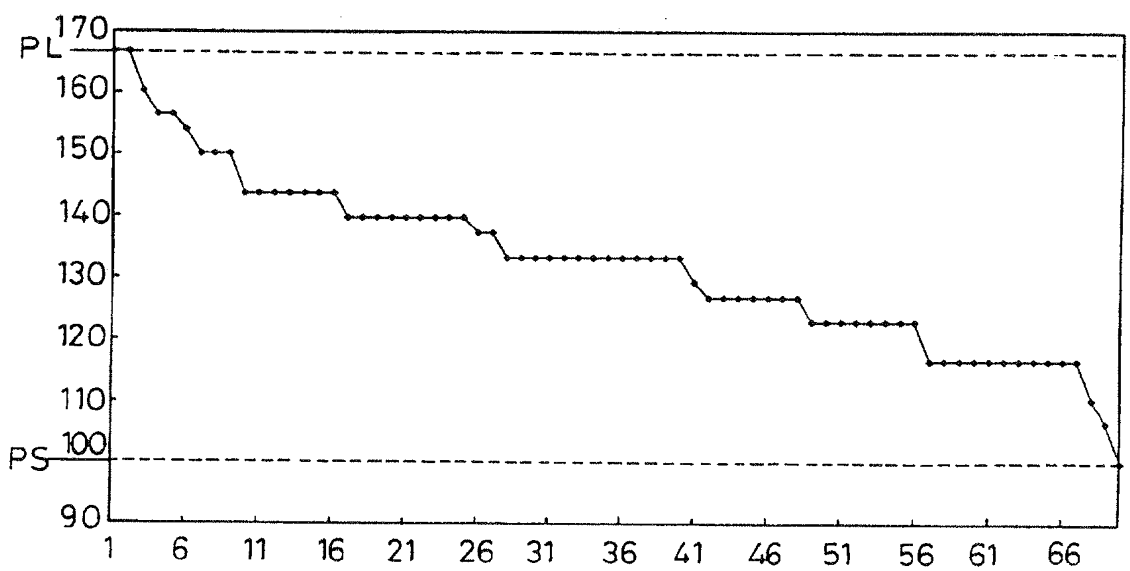
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European Patent Office
Office européen des brevets

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Kobe-shi, Hyogo-ken (JP)

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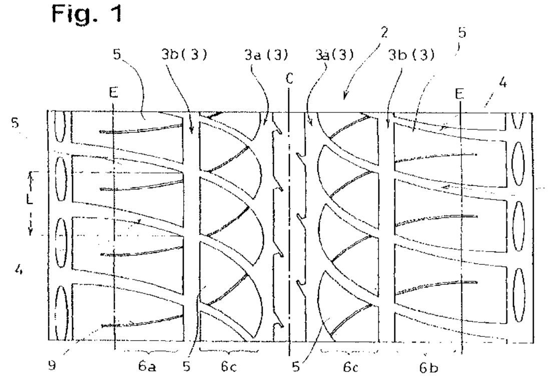
Takarazuka-shi, Hyogo-ken (JP)

(74) Representative: **Stewart, Charles Geoffrey**
Dunlop Tyres Ltd
Fort Dunlop, Erdington,
Birmingham B24 9QT (GB)

(54) **Pneumatic tyre**

(57) A pneumatic tyre comprises a tread portion (2) provided with a series of design-cycles repeating in the circumference of the tyre at variable pitches (L), wherein the number (NP) of different kinds of pitches is at least 10. The variable pitches (L) repeatedly increase and decrease alternately in one circumferential direction of the tyre to define start design-cycles from which the pitches (L) start to increase. A series of design-cycles is composed of a series of units (U), each unit (U) being defined as a group of design-cycles starting from and including one of the start design-cycles to but excluding the next start-cycle. The total number (NU) of the units is from 4 to 20. The units consists of at least one first-unit the number of which is 20 to 80% of the total number, at least one second-unit the number of which is 20 to 80% of the total number, and optionally a third-unit the number of which is 0 to 60% of the total number. The first unit is defined as including at least one pitch which is not less than a standard long pitch (PLa) and at least one pitch which is not more than a standard short pitch (PSa). The second unit is defined as including at least one pitch within one of the following two ranges, a range of not less than the standard long pitch (PLa) and a range of not more than the standard short pitch (PSa), but no pitch within the other range. The third unit is defined as all the pitches therein are more than the standard short pitch (PSa) and less than the standard long pitch (PLa). The standard long pitch (PLa) is the maximum pitch (PL) minus a length of 0.2 times a maximum pitch difference (MPD). The standard short pitch (PSa) is the minimum pitch (PS) plus a length of 0.2 times the maximum pitch difference (MPD), and the maximum pitch difference (MPD) is the maximum pitch (PL) minus the minimum pitch (PS).

Fig. 1



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